The Aquaculture Potential of Indigenous Catfish (*Clarias gariepinus*) in the Lake Victoria Basin, Uganda.

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by

Ajangale Nelly Isyagi,
B. V. M.,
M.Sc. Aquaculture

Institute of Aquaculture
Stirling, Scotland
United Kingdom

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DECLARATION

I do hereby declare that this thesis has been achieved by myself and is the result of my own investigations. It has neither been accepted nor is being submitted for any other degree or qualification. All sources of information have been duly acknowledged.

Ajangale Nelly Isyagi

to my family,

especially mummy

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Abstract

Local and international demand for Lake Victoria's fish has begun to outstrip supply. Production from the fishery has attained its sustainable limits, the diversity of catch has declined and subsequently employment and levels of earnings among fishers have become less secure. Under prevailing conditions, aquaculture offers the most immediate solution to augmenting fish production and sustaining earnings from the sector. It may also provide an avenue through which the diversity of aquatic resources can be increased through for example, the culture of indigenous species; in this case the African catfish (*Clarias gariepinus*), particularly as a polyculture species with conventional tilapia *(Oreochromis*) culture..

To ensure that benefits be derived from the culture of *C. gariepinus*, an assessment of its potential as a candidate species and of appropriate production options was done within the context of fish farmers' local socio-economic, environmental and biotechnical constraints. This was especially necessary because of the persistent poor performance of aquaculture as a farm enterprise among Ugandan farmers and the need to improve their livelihoods. Hence also, a systems approach was chosen as the basic research framework.

The study was conducted in 3 of the 5 agro-ecological zones in the Lake Victoria basin, namely: the Banana Millet Cotton (BMC), Intensive Banana Coffee Lake Shore (IBC) and Western Banana Coffee Cattle (WBC) farming systems. Rapid Rural Appraisals (RRAs) were used to obtain data from a total of 104 fish farming units out of an estimated 212 in the study area. The tools used included semi-structured interviews, ranks and scores, discussions with key informants. Wealth rankings were conducted in 50 villages from which a total of 238 fish farmers were ranked. Quantitative data on farmers' man gement and production was obtained

from a subset of 54 fish farming units. 69 ponds were ampled. Data on the marketability of *C. gariepinus* for table fish was obtained from a total of 25 markets where 65 fish-sellers and 97 fish consumers were interviewed. Information on market potential of *C. gariepinus* as bait was obtained from 14 landing sites where 118 line fishermen and 38 dealers were interviewed.

The information obtained from the RRAs provided an insight into the social, financial and human capital farmers had invested into aquaculture. t also provided information on the environmental constraints in terms of the ability to generate natural ysical capital for aquaculture. The effect of the interaction of these f ctors on farmer's production was analysed using Principal Component Analysis (PCA). Impact on yield was analysed with the PCA in relation to state (inputs), rate (management) and intr nsic (farmers and farm characteristics plus location) variables within the context of fish species currently farmed. The potential entry points for *C. gariepinus* were subsequently derived based on key constraints and marketability.

Poor performance of enterprises was noted by the fact that over 50% of farmers had had no returns, either in cash or food from their ponds. In general, farmer's management practices were adaptive rather than strategic. Key variables causing greatest variance and unstable production in current systems were found to be: (i) se d - notably stocking density, size at stocking, stocking ratios and cost (ii) frequency and larity with which feed and fertiliser were applied (iii) pond size (iv) location within the agro-ecological zones. .Though there was variance between zones, maize bran and cow dung were t e most widely used feed and fertiliser inputs in all zones respectively. It was also found that in a typical polyculture context, *O. niloticus* was the most marketable fish

Two experiments were designed to test comparative economic returns for monoculture and polyculture based on the above findings (i) the effect of stocking density on pond yield and economic returns of O. *niloticus* fed maize bran in earthen ponds fertilised with cow d g (ii) the effect of varying cow dung and maize bran input levels on pond yield and economic returns in *O. niloticus – C. gariepinus* polyculture. The potential of farming *C. gariepinus* as bait was also assessed from secondary *C. gariepinus* hatchery information. The financial returns were assessed based on farmers' actual local costs of production and prevailing local market prices.

Results indicated that (i) farming *C. gariepinus* as either a table fish or bait resulted in higher yields, better returns, improved productivity and utilisation of inputs, better technical and economic efficiency compared to *O. niloticus* monoculture. (ii) *C. gariepinus* in the farming system has the potential to reduce the risk of aquaculture as a livelihood option. (iii) The farming potential and constraints were significantly agro-ecological zone-specific and also influenced by farmers' profiles: therefore different options may be appropriate (iv) It is more important for farmers if yields were defined in shillings based on local costs rather than tonnes, as the units of exchange affecting investment and operating decisions were numbers and size.

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CHAPTER 1

Introduction

1.1. Lake Victoria and its basin

Lake Victoria is the second largest freshwater lake in the world. Its total water surface area of 68,800 km^2 is shared by Kenya (6%), Tanzania (49%) and Uganda (45%) (Serruya and Pollingher, 1983). Its total catchment area is 184,000km^2 and includes Rwanda and Burundi. Lake Victoria and its basin support the livelihoods of a third of the population of East Africa (Kenya, Tanzania and Uganda). The World Bank (1996) estimated that 30 million people lived within the basin at income levels of US $ 90 - 172 per capita per annum. Estimates of the basin's Gross Economic Product were US $ 3 to 4 billion per annum by 1996 (World Bank, 1996). The eco of the lake and its catchment is derived from fisheries (10%), agriculture (35%), industries and mining (15%) and the tertiary sector (40%) (World Bank, 1996; iba, 2003).

L. Victoria has the largest freshwater fishery in the world accounting for 25% of all Africa's inland fisheries yield (Pedini, 1991; Jansen, 2003), with fish exploited as the main tradable commodity from as early as 1910 (Balarin, 1985). The combined export earnings from the lake were estimated to be US$ 600 million annually (Ntiba, 2003). In Uganda, fish from L. Victoria accounts for about 50% of the national catch (which is estimated to be 227,000 mt) and 11% of the country's export earnings (MFPED, 2000; MAAIF, 1999), increasing by 14 times from US$ 5 million to US$ 76 million betwe n 1991 and 2001, making fish the country's second most important export commodity after coffee. Over 700,000 people in Uganda depend on the lake's fishery directly or indirectly for their livelihood (Kaelin and Cowx, 2002; Mutumba-Lule, 1999).

Other than for fish, the lake's water resources are an important source of hydro-electricity; transport; domestic, industrial and agricultural water. The basin's soils and climatic conditions are also favourable for agricultur production, accounting for 59% of Uganda's coffee production (COMPETE and Gowa, 2001), and high capacity for agricultural development (World Bank, 1996). There a e also mineral deposits in the area in Kenya and Tanzania, while its scenery, wildlife and varied cultures also make it a prime tourist destination (The East African, 2002).

As a result of its economic potential, the L. Victoria Basin is among the most densely populated areas in East Africa, with estimated growth ates of 3 to 6 % per annum inclusive of immigration (Ntiba, 2003; Orach-Meza, 2000). According to Ntiba (2003), the population in the basin may increase by 55% in the next d cade because of urbanisation. All of Uganda's major cities and industries are located withi the basin, though most of the population is still rural based and depends on agriculture. During the last fifty years increased human activity has had a great e ct on the natural resources of the area., particularly from changes in land-use patterns (particularly of the wetlands and forests), pollution, over-exploitation of natural resources, and introduction of non-indigenous fish species (Leveque, 1997). This has had an effect not only on the status of the fishery but also other sectors of agricultural pro ion.

1.2. Environmental changes and their impact on the fi hery

The ecosystem of L. Victoria is in a state of flux. It has experienced major and irreversible ecological transformation as a result of e introduction of the Nile perch (*Lates niloticus*) and the Nile tilapia (*Oreochromis niloticus*) from Lake Albert in the late 1950's to early 1960's (Goudswaard *et al*., 2002; Goudswaard and Witte, 1997; Leveque, 1997; World Bank, 1996; Kudhongania and Chitamwebwa, 1 5; Ogutu-Ohwayo, 1990). According to Ogutu-Ohwayo (1990) the Nile perch was introduced to convert the small sized Haplochromines to a suitable sized table fish while *O. niloticus* and *O. leucostictus* were introduced possibly to supplement indigenous stock. *Tilapia zillii* on the other hand was introduced to convert macrophytes into useful fish biomass. As a result, there has been a five-fold increase in catch from the lake (World Bank, 1996), though at the expense of notable loss in biodiversity.

Prior to these introductions, the fishery of L. Victoria comprised some 300 different fish species (Leveque, 1997). Annual average production levels from 1961 to 1984 (with first indications of Nile perch becoming established) were 26,000 t (MAAIF, 1999). Population growth and the consequent market demands have since resulted in increased fishing pressure. Earlier, impacts were more localised, mainly affecting species with low reproductive potential and low resilience. However, since the 1980's, biodiversity declined tremendously and there are now only three major species in the catch: Nile perch (63%), Nile tilapia (15%) and the indigenous *Rastrineobola argentea* (Ogutu-Ohwayo, 1990; World Bank, 1996). Several indigenous sp that were previously commercially important are now considered endangered (World Bank, 1996) (see figure 1.1).

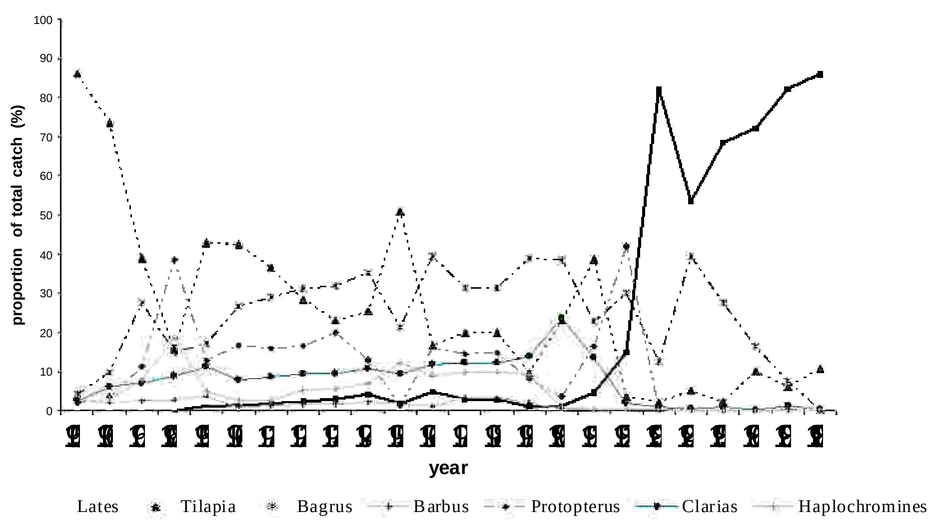

Figure 1.2. Trend in Diversity of Fish Catch, Lake Victoria – Uganda.
Adapted from MAAIF, 1999

(Unfortunately, only data on fish catches up to 1988 are disaggregated by species).

Recent studies by Goudswaard *et al.* (2002), however, indicate that the Nile perch is not the sole cause of decline in species diversity. The authors found *O. niloticus* to be more competitive than *O. variabilis* and *O. esculentus* for limited breeding and nursery space, with higher reproductive success rates. Studies on genetics of L. Victoria tilapias also show hybridisation between *O. niloticus* and *O. esculentus* or *O. variabilis,* with later generations tending to resemble *O. niloticus*. The degree to which this has occurred is still unclear. *O. niloticus* is also a more opportunistic feeder and grows to a larger size.

Eutrophication associated with increased levels of pol s entering the lake has also been cited as a major cause of L. Victoria's decline in biodiversity (The East African, 2002; World Bank, 1996; Scheren *et al*, 2000). Poor municipal environmental waste management, agricultural practices and land use patterns coupled with the encroachment on wetlands have resulted in waste, silt and chemical pollution entering the lake (Scheren *et al.* 2000) Water-borne diseases are reported to have increased as a result of declining water quality, and changes have also resulted in algal blooms, causing transparency values to fall from 5 m to less than 1 m from the 1930's to date (World Bank, 1996). There have been consequent shifts in plankton dynamics from predominantly large filamentous diatoms to small colonial Cyanobacteria and green algae, further favouring *O. niloticus* and also increasing benthic decompositon and the risk of major fish kills, notably of Nile perch, the catfish *Bagrus dogmac* (Forsskall) and deepwater Haplochromines (Goudswaard *et al.*, 2002; Scheren *et al.*, 2000).

1.3. Economic and social impacts

Before the Nile perch became established, the fishery esource was more or less open access, and contributed greatly to rural employment, with small operators in local communities involved in fishing, processing and marketing. A majority of processors and traders were women and a significant proportion of payment for hired labour was in kind as fish. Fishing was the main economic activity and in Uganda, fish was for a long time regarded as the cheapest and most widely consumed source of animal protein (NARO/MAAIF[2], 2000; Owori-Wadunde, 2001; Balarin, 1985). However, since then, the fishery has changed to one influenced by national and international markets, resulting in a diversity of effects, both positive and negative, at individual, household, community, national and international level (ACTS, 1999).

1.3.1. Foreign exchange earnings

Although Uganda's foreign exchange position is healthy, with an estimated surplus of $179m in 2003/4, (MFPED, 2004), this is largely the re lt of aid flows. The balance of trade deficit was estimated at US$712m for 2003/4, well over 10% of GDP. Fish remains the second largest export commodity, after coffee, its export rising to $98.4m (31,000 mt of fish), from $80m in 2001/2 (MFPED, 2004), some 11% of all exports of goods and services, and 16% of all visible exports. This is probably an underestimate as it does not include regional trade (e.g. exports to D. R. Congo). It is unsurprising that the Government, through the Uganda Investment Authority, continues to encourage investment in fish processing for export (UIA, 2005).

However, demand for fish, both for food and as a tradable commod ty, has begun to outstrip supply (Kaelin and Cowx, 2002), Nile perch had become popular in the region and indicated the existence of notable demand for a medium priced table fish (Jansen, 2003). However, local demand has been under pressure from the profitable export trade, pushing up prices and/or reducing available quality on local markets across the region. An illustration of this came when a ban on imports from Lake Victoria was instituted by the European Union, and retail prices of fish in Kenya plummeted from US$1 to US$0.25

per kg. (Oduol, 2000). Increasingly too, tilapia is b filleted for export because export demand is extremely high. *R. argentea* has also been commercialised for animal feed production (Jansen, 2003).

1.3.2. Effect on fishing sector employment

Fishing, handling and processing of fish have become increasingly technical and commercialised. While this may have advantages, particularly in securing international markets, artisanal fishermen, local processors and distributors are being driven out of business because investment costs have increased. Those with little or no formal education have been particularly affected (Jansen, 2003; Mugabe, 2003).

Consequently, the key actors, their roles and ownership patterns within the production sector are changing. The chain is now increasingly comprised of absentee owners, managers, operators and labourers (crew), the former of whom may have no prior experience or link with the fisheries. More fishermen are becoming employees as crew for larger businessmen. More also have contractual agreements with purchasing agents of fish processing factories, who are increasingly dictating the terms of trade, paying higher prices than the local fishmongers and market. They also dictate prices to fishermen, especially in cases where there is vertical integration with processing plants. Fishmongers, as well as local traders and processors, are consequently losing employment. The number of people formally employed in the factories and processing fish factory by-products for domestic consumption in the informal sect r is small compared to those who have lost jobs in the traditional chain (Jansen, 2003).

1.3.3. Over-fishing

The catching pressure on the lake has increased tremendously, driven by this demand and the technical capacity to exploit and process fish has also increased. However, indications are that these far outweigh supply. The exploitation rate of the Nile perch fishery (% of mortality due to fishing) is estimated at 86%, and it would need to fall to 45% to achieve optimal yields. The estimated Maximum Sustainable Yield (MSY) in Uganda's share of Lake Victoria is between 64–76,000 mt. In 2001 approximately 28,000t of finished ish was exported from the lake, equivalent to 70,000 mt wet fish weight, with a total estimated catch of 110,000 mt. excluding exports to local regional markets. Decreasing stocks have combined with an increased number of fishermen, and as a result, the catch has declined from about 80 kg/boat/day to 45 kg/boat/day (Kaelin and Cowx, 2002).

1.3.4 Poverty

Establishing the percentage of people living in povert is not easy, both because definitions of poverty are ultimately subjective and because data on income (and food production) are hard to establish. The Government of Uganda estimates that 38% of the population live in poverty, and average income is below 75c/person/day (given GDP of $250 per capita, MFPED 2004). The other countries of the Lake Victoria Basin do not fare differently: GNI per capita was estimated at $340 Kenya and $270 for Tanzania (UNICEF, 2003).

Among fishers , reduced earnings are attributed both to increased competition for fish and to the decline in catch as a result of over-exploitation pollution, and promotion of exports (MFPED, 2002). They have been less able to take advantage of the expanded markets because of the limitations they face in accessing financial and human assets such as equipment and skills. The influence of the seasons on catch, lack of storage facilities that leads to high post-harvest losses (estimated at 15-40% in Uganda) and the high dependence on a single source of income have made it increasingly difficult for small-scale fishers to earn a living from fishing (MFPED, 2002; Kaelin an Cowx, 2002; NRI and IITA, 2002). More of the money earned is going to the larger businessmen, fish processors and the state rather than directly to the local fishermen, fishmongers and traditional fish processors. There is also very little re-investment at the local level by all parties involved, particularly at sites not used by fish factories (The East African, 2002).

1.3.5. Levels of malnutrition

The factors discussed above have contributed to a decline in Uganda's per capita food production of 44% from 1970 to 1997 (Bahiigwa, 1999). Up to 95% of rural households in Uganda depend on their own food production as a mai source of food. Rapid population growth coupled with declining productivity s resulted in an increased need for additional food sources (Hazell, 1998; MAAIF and MFPED, 2000; The East African, 2002). More households have therefore had to turn to he market as a source of food. Low and declining rural incomes are therefore a concern for food security (Bahiigwa, 1999; MAAIF and MFPED, 2000).

Despite the local economic opportunities, being close to the lake has not necessarily brought nutritional advantage. Even fishermen are now consuming less fish, which has become too expensive. Studies conducted by the Kenya edical Research Institute found 30-50% of children to be moderately to severely malnourished among the riparian communities of L. Victoria in Kenya. Out of these, 60-70% of the malnutrition was attributed to lack of zinc, iron and vitamin A that co be obtained from *R. argentea* ('dagaa'/'mukene') (Mugabe, 2003). UNICEF (2003) figures indicated that the nati nal incidence of chronic child malnutrition (stunting of under-fives) was 23% in Kenya, 29% in Tanzania and 23% in Uganda. In Uganda as a whole, stimated per capita fish consumption, based on national catch and fish export figures, has declined by 61% since

1971 (Balarin, 1985; UBoS, 2002; MAAIF, 1999).

1.4. Aquaculture as a potential mitigation measure

For the ordinary rural smallholder farmer in the basin, agricultural productivity has declined despite potential. This is attributed to several compounding factors: the extensive farming methods practised by the majority of farmers that are so vulnerable to natural hazards; a long-term decline in terms of trade for agricultural produc making investment less attractive; unequal gender relations; emographic pressures and subsequent land shortage; limited options for rural non-farm income; and lack of energy sources (MFPED, 2003). Levels and effects of poverty have been further aggrava ed by HIV/AIDS (The East African, 2002). NEMA (1999) further links the increasing levels of poverty among the rural farming population with the decline in national agri ural yields and productivity and with increased environment degradation. Like the artisanal fishers, small-scale farmers' ability to derive benefits from economic growth programmes focusing on the ability to exploit already existing capabilities has been constrained by their limited assets (Okidi and Mugambe, 2002 and MFPED, 2002). Because of their lack of financial and human assets, production options are limited to those that depend heavily on climatic patterns. Consequently, they experience periods of relative abundance and hardship in tune with the seasonal natur of primary production, income-generation and expenditure. The nature of poverty amo small-scale farmers in the lake basin (as elsewhere in Uganda) is therefore cyclical, seasonal and chronic, which makes it difficult for them to invest in long-term sustainable management options (MFPED, 2002). In order to mitigate the effects of 'seasonality' and he risks associated with changes in climate, farmers have turned for survival to the use of marginal resources and ecologically sensitive areas such as the fisheries, fo and wetlands (NEMA, 1999).

Given the need to maintain exports and the simultaneou need to reduce poverty, it is evident that the fisheries sector has to enlarge, but a manner that ensures local food security and livelihoods and maintains the future yields of the fishery (Jansen, 2003; Swick and Cremer, 2001; Kaelin and Cowx, 2002; Balarin, 1985; Rana, 1997, King, 2002). Food security will only be improved if additional ish produced is affordable for the poor, which means expanding its supply (Tacon, 2001; Lem and Shehadeh, 1997). Aquaculture offers a potentially non-exploitative option for expanding fish production and sustaining the contribution of the fisheries to th national economy. It is for this reason that the Lake Victoria Environment Management Project (LVEMP) opted for aquaculture among its key interventions in fisheries. The LVEMP was set up to rationalise natural resource use in the basin, with the of re-establishing ecosystem integrity on a sustainable basis.

By targeting endangered indigenous species that are of high market value, it is hoped that the loss of aquatic resources can be ameliorated through aquaculture. The species of focus at the start of the project included *O. esculentus, O. variabilis, L. victorianus, B. docmac* and *Protopterus aethiopicus (*World Bank, 1996).

1.4.1. Status of aquaculture

Aquaculture is promising for many reasons (UNEP, 1990; Shang, 1990; Chopak and Newman, 1998, Lightfoot et al, 1994; Goletti, 1999; Ta on, 2001), among which the key arguments for Uganda are that it offers:

i) potential for low-risk agricultural diversification which is easily integrated into many existing farms (where water is available).

ii) mitigation against seasonality in both capture fisheri nd agriculture.

iii) to help meet demand beyond the natural sustainable capture fishery yield.

iv) to help foreign exchange revenues, by sustaining higher export levels.

v) significant potential as a much needed source of high-quality animal protein and other essential nutrients.

vi) an efficient way to recycle nutrients from the farm (into both protein and nutrient rich pond mud), giving savings which have been valued at up to 40% of gross farm income (Lightfoot et al., 1994).

Aquaculture in Uganda was started in 1931 and an experimental station set up in 1953 at Kajjansi, now in Wakiso District which is within the L. Victoria Basin (Balarin, 1985). According to a recent strategic assessment of aquaculture in Af a by Aguilar-Manjarrez and Nath (1998) the potential within the basin is high for both small-scale and commercial aquaculture. Similar conclusions have been drawn in a socio-economic assessment by Nanyenya *et al.* (1999) on technology adoption, the profitability and competitiveness of aquaculture in Uganda.

However, aquaculture's contribution to the agricultura sector has until now been insignificant. National aquaculture production is est ed to have increased from 31 mt to just 360 mt between 1985 to 1999, accounting for only 0.2% of national catch (Balarin, 1985; Kaelin and Cowx, 2002). Of this total, aquaculture in the L Victoria Basin accounts for about 17%. According to Fisheries Depart ent estimates of 1997, there were an estimated 1,085 ponds covering 21.3 ha in the basin (MAAIF, 1997).

The above estimates were however not based on actual d a from pond harvests, but on calculations from theoretical yields. It was assumed at farmers should be getting 275-300g/m² per year. Indications are that actual yields are much lower, from just 28 g to 138 g/m²/yr (KARDC, 2000), and so the actual total national harvest is probably only 50 to 150 mt per year. Even the theoretical figure of 360 t still leaves production much lower than the estimated 11,000 t of the late 1960's (Balarin, 1985). Persistently low yields and poor yield quality have had a negative impact on profi bility, and consequently, there are many abandoned fish ponds. However, despite this, aquaculture offers the only option to increase fish production from the basin. More importantly for the potential fish farmers concerned, aquaculture continues to show significant p ential for helping farmers increase their household income. Its history of failure has not been shown to be due to inherent or insurmountable problems. The economic difficulties facing the population in the area, including the problems with fishing in Lake ictoria already discussed, the long-term collapse of the price of the main cash crop, coffee, and the difficulty in finding alternative cash crops, mean that the search for profi nd sustainable aquaculture is a worthwhile investment.

1.4.2. The potential for aquaculture under the prevailing conditions

The natural resource potential for aquaculture in the ake Victoria basin is regarded as favourable (Balarin, 1985; Anquila-Manjarezz and Nath, 1998). Economic potential is higher than ever, as the value of fish rises, particularly for several highly prized indigenous lake species. However, potential benefits can only be realised if systems are appropriate and sustainably managed so that they have positive or at least neutral effect on local natural resources and farmers' livelihoods. appropriate system is one which fits the farmer's goals – their opportunities are financially determined, performance linked, aimed at profits and at the enterprise's resil ce (Muir and Young, 1998). Too often, on the other hand, research takes a uni-dimensional perspective of maximising yield in kilograms per unit area.

Farmers are not generally interested in ecological issues of increasing national harvest, but only as a means to better income and food security. Aquaculture has to show that it offers a competitive advantage compared to their other opportunities, d though this might be the case (see below), it is a challenge to ma it work. This thesis is one response to that challenge – a contribution to finding a production model that meets the needs of farmers in the Lake Victoria basin.

1.4.3 Why indigenous species?

Aquaculture in Uganda could in principle largely be revitalised through the introduction of an exotic, high-performing species. Although this may not meet a conservation objective of preserving endangered lake species, for aquaculture to thrive, it must meet farmers' objectives, not just those of the State. This thesis sets out to examine production possibilities that meet farmers' objectives and are appropriate for their assets and livelihood possibilities: in that case, reasons for choosing to research an indigenous species need to be justified.

The benefits of introducing exotic species should not be exaggerated, as their track record shows that they rarely offer an advantage. In Asia, there have been 517 introduced species, over 20% of the number of indigenous freshwat species (2,943). However, exotics only contribute 5 % to total production (Brummett, 2000). In Africa, exotics have resulted in a slightly higher level of 15 % of output, though 99% of this comes from one species (common carp, *Cyprinus carpio*) in just two countries (Egypt and Madagascar). The vast majority of introductions in Africa have failed to produce harvests of even 10 mt a year.

The main reason for this is because the germplasm being cultivated has rarely been the constraining factor. Some of the constraints in Uganda were discussed above (poor policy, a research agenda that did not respond to farmers needs) and others will be detailed later (e.g. inadequate inputs, shortage of seed, lack of research and extension to give farmers viable management systems) (KARDC, 2000; Isyagi, 2001). Exotic species tend to fare worse than indigenous species when it com to most of these constraints, in particular for research and extension and for seed supply. Indigenous fish also end to have market advantages, since most consumers are conservative and reluctant o buy unfamiliar fish.

In Uganda, though there may be opportunities for larger scale production for domestic and export markets, there is an important case for aquaculture research to prioritise the needs of the small-holder sector – the vast majority of the rural population, many of whom live below or close to the poverty line. Experience has shown how even larger scale enterprises failed when support institutions collaps d during the years of Uganda's turmoil, and although social and political stability is somewhat improved, markets for commercial production would need to be developed, and isks remain. Small-holders can less afford dependency on inaccessible services, when he costs of their time and transport to facilities for advice or for seed can out the potential profit from small ponds. Hatcheries have had difficulties in maintainin rood fish for indigenous species, though there are adequate stocks which can be found in the wild: if there are inadequate reserves of exotic brood fish, there is a major danger of inbreeding (Brummett 2000).

It is recognised that small-holder farmers have to prioritise system resilience (i.e. low risk) as highly as optimal profit potential. Risk comes from growing fish with an uncertain market, growing species which may not prove o be well adapted to local ecological conditions, and from production systems with expensive, inaccessible or unfamiliar inputs. It is far easier to generate knowledge on production of indigenous fish (diseases, feed, pond design, etc.) than for exotics. The more expensive the techniques for producing seed (e.g. investment in new facilities), the higher the cost will be for farmers. Since indigenous species are adapted to local conditions, they are more likely to tolerate local variations in pond conditions. These are inevitable given the way farmers inherently have to adapt any given technology because they are continually responding to circumstances rather than acting out a pre-planned management regime.

The choice to investigate an indigenous species is the efore not ideological, but because it is more likely to have a market in rural areas, be easier for farmers to reproduce, be more suitable for *ad hoc* adaptation in management plans, to involve lower investment costs and generally to be of lower risk. However, it not en gh to argue this on theoretical grounds: any proposed production system must in the end be tested and prove itself on exactly these criteria.

The African catfish (*C. gariepinus*) is a promising candidate species: it is known to have a good market, captive breeding technology is already available, and farming technology is well established elsewhere at commercial level – both as small and large scale enterprises. Nevertheless, the need for thorough preliminary research is clear. Aquaculture in Uganda has consistently failed to perform, and it would be wrong to try and introduce a new species into a context of chronic failure without fully understanding the nature of the problems with the sector. If a goo diagnostic can be made which explains why the progress of aquaculture has been so difficult, and if research can also indicate which measures can be taken to ameliorate the problems, the there will be reason to believe that a new technology may successfully be introduced. That is the challenge of this thesis research.

CHAPTER 2

Review of Research Approaches

2.1. Introduction

It has long been understood that diversity in small-holder production systems is not the result of the execution of a theoretical plan, but a farmer's effort to manage and react to the complex interaction of biological, environmental a d socio-economic resources in accordance with his/her preferences, capabilities and available technology (World Bank, 1991; Engel, 1995; Shehadeh and Pedini, 1999; Machena Moehl, 2001). Their agricultural production systems are dynamic, complex a diverse because they continuously evolve in response to local production constraints (Harrison, 1987; Brummett, 1994).

Fish farmers in the country are characteristically rur smallholders for whom farming fish is one of several farm enterprises (NARO/MAAIF[2], 2000). It is necessary to take into consideration many factors at the same time when eveloping appropriate technological innovations for such farmers that they c n adopt (and adapt) (Doss, 2001). The use of resources in such options should be commens rate with local resource constraints and objectives. To assess the way in which aquaculture, or the production of a particular species, may be incorporated into farming systems, it is necessary to identify and consider the range of factors affecting potential ke, development of production, and marginal risks and returns to the proposed developments. Identification of potential entry points for the African catfish (*C. gariepinus*), as any other fish, will consequently be best assessed based on a sound understanding of current production systems and their dynamics. An understanding of the full picture will h develop technologies with a better fit to the complex livelihood strategies of the farmers. In this sense, it is preferable to adopt a holistic analytical approach that puts emphasis on the comprehensiveness of the system and analyses the object under investigation in view of its relationship with the overall system.

In aquaculture, the systems approach has been identified as most suitable for identifying key research issues, developing improved management alternatives including the designing and testing of new systems among small-holder farms in developing countries (World Bank, 1991; Tacon, 2001; Sorgeloos, 2001; Phill ps *et al.*, 2001). In this approach, the farm or farming household economy as a whole ('the system') is analysed as a single entity, rather than looking at one component (e.g. a fish pond) in isolation. The farm is seen to comprise multiple activities each of which affects the others, o one set being understood without reference to the others. The 'system' as a whole determines the investigations to be carried out, according to farmers' overall livelihood goals – which they try and achieve not through any one enterpr se on its own, but by balancing various components of the system, which may sometimes compete and at other times complement each other. This then requires a multi-disciplinary analytical framework. Such a view cannot be obtained from a reductionist or disciplinary approach, which is more relevant for longer-term research along innovative lines, or for following up specific technical issues identified by the systems ap ach. This also necessitates combining qualitative and quantitative approaches. It is first necessary to understand which parameters in a system are important and need to be quantified, and this can only realistically be handled using qualitative enquiry. The subsequent quantification of these parameters will then enable objective hypothesis testing, because it can ensure a) that bias is removed or accounted for and b) relationships that are not appar to system actors can be revealed.

2.2. Factors likely to influence the potential of far ing *C. gariepinus*

Other than income, sustainability for such farmers implies that the capacity of the technology to respond to and withstand local stressors is important. There is also a goal to improve livelihoods. Such interventions might be achievable if based on an analysis of stakeholders' assets and the local characteristics of poverty. The possible effects of interventions on local food supplies and markets also eed to be taken into account (Berdegué and Escobar, 2002; Machena and Moehl, 2001). Hence the study used a participatory approach to assess the effect and possibility of utilising farmers' local socio-economic, environmental and technological resource to roduce *C. gariepinus* as a potential sustainable livelihood option.

2.2.1 Sustainable Livelihoods Framework

The starting point of the research was to come up with recommendations which would be useful, contribute to poverty alleviation, and benefit poor farmers. The sustainable livelihoods framework is a useful way of analysing livelihood options, and was therefore used as an overall structure within which farming systems analysis was carried out. It has already been introduced into forestry extension servic in Uganda with positive impact (Goldman et al., 2001, Harrison *et al*., 2004).

The sustainable livelihoods framework makes personal, household or community assets the centre of its analysis, rather than starting with rty or problems, as in a needs based analysis (Dorward et al., 2001, Carney, 1998). Here it is appropriate to recognise different kinds of capital or assets: human, natural, financial, social and physical. However, rather than merely listing these assets, the ework is dynamic:

- it allows the analysis to see interactions between dif erent kinds of capital and how one kind of capital can be turned into another;

it shows the different livelihood functions which assets can have for different people at different times.

it can capture resource flows

Focusing on assets has two important consequences. First, it enables a technical researcher to concentrate on people's opportunities, rather than on their problems. This creates a common language between the technical specialist and the rural poor (and between the scientific researcher and the literature on poverty). Secondly, it guides the research agenda and helps ensure that recommendations are practical. A disciplinary scientist may look to maximise yield from a pond, for example by increasing stocking densities. An economist may seek to increase profitability by increasing the scale of the enterpris o improve economies of scale. A livelihoods framework ensures that the farmer's assets are considered: do they have enough manure to follow the recommendations? What other livelihood functions does the manure have? How do the resource flows of manure vary with the seasons? Such questions must be the starting point for research, and not problems to solve once the research is over.

2.2.2. Socio-economic factors

Aquaculture in Uganda has not particularly thrived ove the past years. The reasons for its mediocre performance have largely been socio-economic, at both the macro and micro levels.

At the macro-level, weaknesses in Government policy have been cited the reason for the poor performance and growth of fish farming across sub-Saharan Africa (Harrison, 1984; Pedini, 1997; Hecht, 2000; Brummett and Williams, 2000; Machena and Moehl, 2001; Phillips *et al*., 2001). Historically, Government institutions determined farmers' access to resources for production and to markets and edit. Aquaculture was often regarded as a 'novel' venture, encouraged by institutions which relied he on external support and direction. This resulted in a top-down approach to technology development and transfer in which the farmer's perspective was str kingly absent from consideration.

As a result, production ventures were as unsustainable as the institutions which supported them. In addition the public sector (and increasingly the voluntary sector) remained for a long time the sole provider of technology, key technic inputs (notably seed and nets) and services. Little was done to harness the potential of the private sector to provide essential inputs and services.

This resulted in production options and Government sector objectives that failed to develop in line with farmers' changing conditions, and consequently became incongruent with local needs and capabilities[1] (Hecht, 2000). The fact that farmers were not equipp with the skills to manage and adapt technology to suit their local needs also meant that their production was vulnerable to operational and technical risks. These risks proved to be high, given failures in the public system to deliver the necessary inputs and services. This compromised the sustainable development and growth of aquaculture.

To address this, it is necessary to start by understanding the producer – their assets (or 'capitals') and their constraints (the level and natur of their poverty) (Berdegué and Escobar, 2002; Machena and Moehl, 2001). The primary unit in a farming system is the farming household, which decides the use of resources at its disposal according to its economic aspirations, socio-cultural values and capabilities (World Bank, 1991). How effectively resources are harnessed to achieve livelihood goals is influenced by the household's managerial ability. This is a function of its human assets such as the age of the farmer(s), their level of knowledge and skills, labour availability and attitudes (Panayotou *et al.*, 1982).

Where income is part of a farming household's economic objective the role of the market is important. Local markets influence the choice of species farmed, desired productivity levels and affect investment and the diversification o agricultural activities (Balarin,

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[1] So for example for a long time, national development objectives centred on household food security defined narrowly as food production, when farmers' objectives had shifted towards income.

1985; Ruben and van Ruijven, 2001; Deininger and Okidi, 1999). Among farming households where economic and social constraints are t access to finance for purchase of inputs is constrained due to the high risks associated with rain-fed production and the high cost of borrowing. Risk minimisation, the resilience of an enterprise and family persistence consequently become added concerns or poor rural households (Hishamunda *et al.*, 1998; World Bank, 1991; MFPED, 2001). It is also important that new technologies have the capacity to reduce the margi al costs of production in view of farmers' constrained access to finance (Berdegué and Escobar, 2002).

2.2.3 Environmental factors

Farmers' ability to access and utilise resources from he environment for production is determined by their human, financial and social assets and their alternative livelihood options (Altieri and Nicholls, *unpublished*). It is generally acknowledged that an aquaculture site can only be managed with regard to th whole ecosystem (GAMBAS, 2002). Local ecosystem characteristics determine what natural assets are available to the farm for production and, together with socio-economic characteristics, what technological solutions are appropriate. In small-holder agriculture, agro-ecosystem and socio-economic factors determine what technological solutions are appropriate rather than the reverse, because they affect the dimensions of poverty and the supply of potential uts (World Bank, 1991; Gomiero *et al.*, 1997; Ellis and Bahiigwa, 2003). The natural resources accessible to the farmer therefore determine which species can be cultured, the design and management options, and possible production and productivity levels. Consequently where fish farming has been properly integrated with local natural resource capacity it can have positive effects on the farm environment. Examples of improvements in farm ecological integrity, productivit and incomes for small holders include integrated pest management in rice-fish farming, watershed ponds in watershed management and flood plain fish farming, credited with replenishing diminished wild fish stocks in South East Asia (Barg and Phillips, 1997; Phillips *et al.*, 2001).

The close relationship between aquaculture and the environment also makes it susceptible to environmental degradation (Beveridge *et al.*, 1997; Diana *et al.*, 1997). Environmental degradation caused by increased population pressure on forests has been cited as among the major causes of the collapse of the traditional aq culture systems of Madagascar, Côte d'Ivoire, Benin and Ghana. Likewise poorly established fish farms can have negative impacts on the environment that may lead to p llution, habitat destruction and outbreaks of fish disease (Swick and Cremer, 2001; Barg and Phillips, 1997).

2.2.4. Bio-technical factors

The bio-technical aspects of aquaculture include the species cultured, th culture facility and husbandry techniques (Brummett, 1996; Edwards, 1998). The biological attributes of the species chosen for culture determine facility design, husbandry techniques and production levels. Technical aspects determine the level of productivity of the resources available to the system.

A total of 21 species have been investigated for aquac e in Uganda, of which only five were indigenous fishes from Lake Victoria (Balarin, 1985), *Protopterus aethiopicus*, *Bagrus docmac*, *Oreochromis esculentus*, *O. variabilis* and *Mormyrus sp*. However, only two species, neither of which is indigenous (*O. niloticus* and *Cyprinus carpio*), were adopted in the 1960's for culture because of the then echnological limitations in seed production and management of other species. In addition the focus for aquaculture was to provide supplementary protein to households, partic ly in areas far away from natural waters. The amount and diversity of lake fish available in the local markets was also considered adequate, so there was little comparat conomic advantage in farming fish close to the lake. Low-input low-output technologies were therefore adopted, as levels of production were aimed at meeting household demand.

Production incentives have since shifted towards the m and fish farming technology the world over has become more developed. The diversit of species from the lakes available to the market has also declined, and indigenous species now have greater opportunity in aquaculture. However, production system may need to be more efficient within the framework of local infrastructure, supplies and services to satisfy farmers' objectives. Technical innovation in the transition fro ic to indigenous species, and from subsistence to market oriented production would be best achieved by increasing yields and income without threatening food security, raising debt and dependence of fish farmers and/or exacerbating local environmental degrad tion (Tacon, 2001). So for example, issues such as seed supply in relation to effects on wild stocks need be taken into account. However native species have the potential to be a sustainable option: wild stock is locally available for improving farmed stock, there are fewer negative impacts associated with loss of species diversity in the wild and indigenous species are often more suited to local environmental conditions (Brummett, 1994).

Nonetheless, whatever the technical suitability of *C. gariepinus*, it must be able to perform "socio-economically", i.e. using technology commensurate to farmers resources and in production systems which meet their objectives. Socio-economic factors, such as incomes, markets, farmers' skills, etc. therefore need to be considered.

2.3. Analytical approach for assessing small-holder production potential

To capture all the relevant parameters, the research used a variety of tools, both quantitative and qualitative. These are discussed in this section.

2.3.1. Qualitative methods

Participatory assessments

Several authors recommend participatory procedures as nostic techniques for assessing opportunities and constraints among rural small-holder farmers within the context of their local resource constraints (Chambers, 1989; Townsley, 1996; Machena and Moehl, 2001). These have been derived from a range of anthropological methods and rural development tools, notably Farming Systems Research (FSR), Agro-Ecosystems Analysis (AEA) and Integrated Rural Development (IRD) (Pido, 1995). They employ a bottom-up approach to research and development by facilitating a joint multi-sectoral approach to analysis between beneficiaries, s akeholders and researchers through all stages of the process. They acknowledge a build on the fact that farmers are not just recipients or reproducers of knowledge but creative managers and integrators of knowledge and information, pooled from many sources, including their own practical experience. The significance of diversity of farmers, including gender and economic class in resource allocation, utilisation and consumption is also fully considered.

Participatory tools are flexible in their approach, permitting the adaptat of procedures during the research process to suit specific local situations (Sumberg and Okali, 1989; Naegel, 1995; Pido, 1995). Adaptations can be made because the tools used for data collection derive from a pool rather than a fixed set f recommended procedures. These attributes are important, especially when dealing with farmers and environments with diverse constraints. Furthermore they permit on-the-spot analysis of data during the process, permitting early detection of limitations in selected tools, all wing for immediate rectification or adaptation to improve the quality and relevance of data obtained. The reliability of data is enhanced through triangulation, using different sets of tools to generate comparable data. This helps reduce biases attributable to social and physical factors that may impede information flow between the researcher and farmer/stakeholder. These attributes make participatory tools very effective in assessing complex and diverse production settings.

In this context Rapid Rural Appraisal (RRA) is designed to generate basic information for planning, development and research (Pido, 1995; Townsley, 1996; University of Stirling, 1998). It is considered a rapid and cost effective way of learning about an area before deciding which development interventions could be relevant or merit more in-depth study. They may be exploratory or have a specific focus. In RRA, the level of stakeholder participation is limited to information ge ation. Participatory Rural Appraisal (PRA), set more broadly, has more social and political connotations, and is designed to respond more to community, its needs and development. Its primary aim is to stimulate local people's own analysis, action and mobilization of local resources by devolving management responsibilities to them. It is equently less defined than RRA, which makes it more difficult for a researcher to achieve pre-set objectives, as the community determines the research course. Unless very carefully set out, these techniques can also become limited in their ability to account for stratification within communities (Townsley, 1996).

RRA was considered to be more suitable here in view of the study objectives: to obtain information from farmers on their aquaculture constraints that would be used to assess the potential and design potential production systems. However, although methodologies such as RRA, are considered to be rapid, cost efficient and effective, they have limitations. While they may enable researchers to ask the right questions, some consider them to be too 'quick and dirty' (Pido, 1995; Orr and Mwale, 2001; Gladwin *et al*., 2002). Users of such tools may at times 'ignore' farmer variation and focus on similarities. They are also criticized as they have no inherent procedures to test universality (White, 2002), compared with hypothesis t ng in basic science. However, these shortfalls can be partly overcome by proper data handling, and by employing statistical procedures so that hypotheses can be tested and/or derived..

Exploratory RRAs were therefore undertaken to obtain the following:

- an understanding of the behaviour of, and interrelations betwee he different parts of the farming systems;
- knowledge of the basic objectives of the decision make naging the enterprise, and factors likely to influence management decisions, and
- an understanding of the system as a whole in its agro-eco-regional context.

Wealth rankings

Wealth plays an instrumental role as different forms o capital in the economic lives of rural farmers (Berdegué and Escobar, 2002; Ellis and B 2003). It determines their access to resources and the viability of their livelihood options especially in relation to risk and choice (for example, when to sell or buy). Understanding farmers' wealth is more than a simple measure of their resources in the material sense, but needs to include their own assessment of their livelihood opportunities (Bebbington, 1999).

In wealth ranking, wealth criteria are set by respondents, and data represented an ordinal scale. These have an advantage over traditional surveys, because of their ability to generate information on multiple dimensions of wealth. The complex context of rural household wealth, its regional and ethnic variations c be inadequately represented by the fixed sets of quantitative variables generated from traditional surveys. Data on household consumption and expenditure may not always be reliable, as few rural households keep records, and quantification in currency units removes the qualitative contextual information necessary to verify and interpret it. Wealth ranking is therefore very useful to complement survey and census data on household wealth where they exist, and, in their absence, is a relevant, efficient and cost-effective alternative (Adams *et al*., 1997; Takasaki *et al*., 2000). It is able to capture a diversity of information because respondents are allowed to incorporate a wide range of wealth measures, and value them using their own defined local weights. Consequently it is possible to pick out differences that appear small or irrelevant to outside observers but have profound influence on local natural resource access and use, decision making and w fare outcomes.

However, their validity and reliability have sometimes been questioned, because when respondents assign a 'wealth rank' to households, it can be difficult to verify how criteria were applied. This potential quantitative unreliability is offset, though, by their ability to overcome errors associated with respondents' recall, a with sensitivities and expectations common in traditional studies. Studies by Takasaki *et al*., (2000) validated wealth rankings against standard socio-economic indicators derived by questionnaire survey. Their study indicated that local informants were able to differentiate households accurately according to an array of culturally appropriate wealth criteria and to strat y households sufficiently well into correct wealth group Errors in assessing asset possession rates were low for productive capital but higher for consumer goods and certain types of productive land. Errors were also found associated with under-ranking of households and in differentiating bottom and middle groups, between which actual differences tended to be small. The authors noted that weaknesses could be overcome by not drawing inferences from wealth portfolios based on single household features.

2.3.2. Quantitative methods

The procedures described above often yield large sets of largely qualitative data. As these data sets are complex, and subject to methodological limitations, a combination of methods is recommended. This is known to yield greater insight in such situations han the sum of the various approaches used independently (White, 2002). Qualitative and quantitative methods used together provide a richer ba for analysis, opening up areas for enquiry and facilitating interpretation of data (Adato and Meinzen-Dick, 2001).

Factor analysis is a set of techniques for analysing interrelationships among a large number of variables and for explaining these variables in terms of common underlying dimensions (factors). Unlike dependence methods (e.g. multiple regression and analysis of variance), these look at interrelationships among variables, and no variable is explained by (or predicted by) any other. When there are too many inter-acting variables and it would be almost impossible to make sense of all the correlations, factor analysis helps to look instead at the overall structure in the ata. They are therefore less suitable for prediction (or hypothesis testing) because there is no *p*-value; it is for the researcher to interpret the output of the analysis to generate plausible assumptions and hypotheses about how a system works (Cuenco, 1989).

Hence, they are exploratory techniques and seek to generate hypotheses rather than test them (Chatfield, 1995) by picking up on key variables that n provide useful information (Cacho, 1997; Phillips *et al.*, 2001). This makes it possible to derive a small and flexible set of experiments or options that will be much less costly and potentially more useful than a large set of experiments that will generate masses of data. Examples of multivariate methods that have been used to this effect include principal components analysis, cluster analysis and principal co-ordinates (Riley and Alexander, 1997).

Principal Component Analysis (PCA), one of the main forms of fa r analysis, was chosen for this study, as it can combine highly heterogeneous groups of variables into single components. It empirically assesses the structure of variables, from which it creates composite measures (components) or selects subsets of representative variables that can be used for further analysis (Hair *et al*., 1998). The limitation of PCA is that as a linear technique it will not pick up non-linear correlations.

PCA's ability to combine different kinds of data (quantitative, qualitative, etc.) is an important attribute, as in most situations the weighting and quality of infor ation is not as constant or uniform as in controlled experimental conditions In aquaculture, PCA has been found useful in understanding production systems and identifying key constraints of smallholder farmers in India (Veerina *et al*., 1999). In Vietnam, a combination of multivariate techniques, including PCA, common factor analysis and cluster analysis were used to devise sustainable aquaculture systems in the Mekong delta that were technically feasible, environmentally compatible and e onomically profitable (GAMBAS 2004).

Principal components comprise a set of variables which, when acting in combination, have a strong influence on a certain parameter (e.g. y eld). The combination of variables with the greatest effect are assigned numbers in decreasing numerical order, i.e. PC1, PC2, etc. The variables are assigned positive or negative coefficients depending on what trend their effect is on the given parameter. It beco possible to identify key variables from large multivariate sets, allowing a researcher to 'zero in' on a few manageable variables for further study, hypothesis elaboration and testing, or for experimentation. In this study, PCA was used to: identify key production determinants/ constraints; examine how these factors currently influence production; and identify production opportunities for indigenous species in the system.

2.4 Study strategies

The study assesses the relevance of *C. gariepinus* as an option for aquaculture. The relevant factors were considered to be: the economic context (potential markets and price), the environmental context and farmers' resource constraints (notably feed and fertiliser inputs and access to seed). From these, different culture systems were chosen for testing, with two key variables of seed input (species, quality) and pond management.

2.4.1. Seed supply and demand

Among the major exogenous factors affecting the viability of a production system, is the availability of seed. This is recognised as being among the major determinants affecting farmers' adoption rates and sustainability of producti n (Hoekstra, 1994; Little *et al*., 1996). The lack of seed, in terms of physical access, q ality and price, has seriously constricted aquaculture development in Uganda (as in much of sub-Saharan Africa) (Machena and Moehl, 2001; KARDC, 2000).

2.4.2. Management options

The principles of pond farming focus on creating a suitable environment for fish growth and increasing production and productivity by manipulating its environmental conditions. Key inputs manipulated are the type, quantity and quali of fish seed, feed and fertiliser. Water is sometimes quantitatively and qualitatively adjusted depending on the intensity of farming (Nath *et al.*, 1995; Diana *et al.*, 1997). Appropriate management options are based on the optimal use of scarce resources to achiev desired farm objectives. For producers and extension personnel, the problem generally relates to the choice of optimal management practices and outputs in the face of changi g exogenous forces associated with environmental, bio-technical and socio-economic constraints (Weersink *et al*., 2002). As discussed above, in their pursuit of higher and profits, farmers commonly modify their practices by manipulating and substituting input combinations (Veerina *et al*., 1999).

CHAPTER 3

Methodology

3.1. Introduction

The objective was to assess which aquaculture production options would be most appropriate to farmers given their local constraints. A holistic approach was chosen, using concepts of the sustainable livelihoods framework for analysis. This was further linked with market and consumption data to determine viability and returns to farmers. The detailed framework for data collection and analysis is shown in figure 3.1.

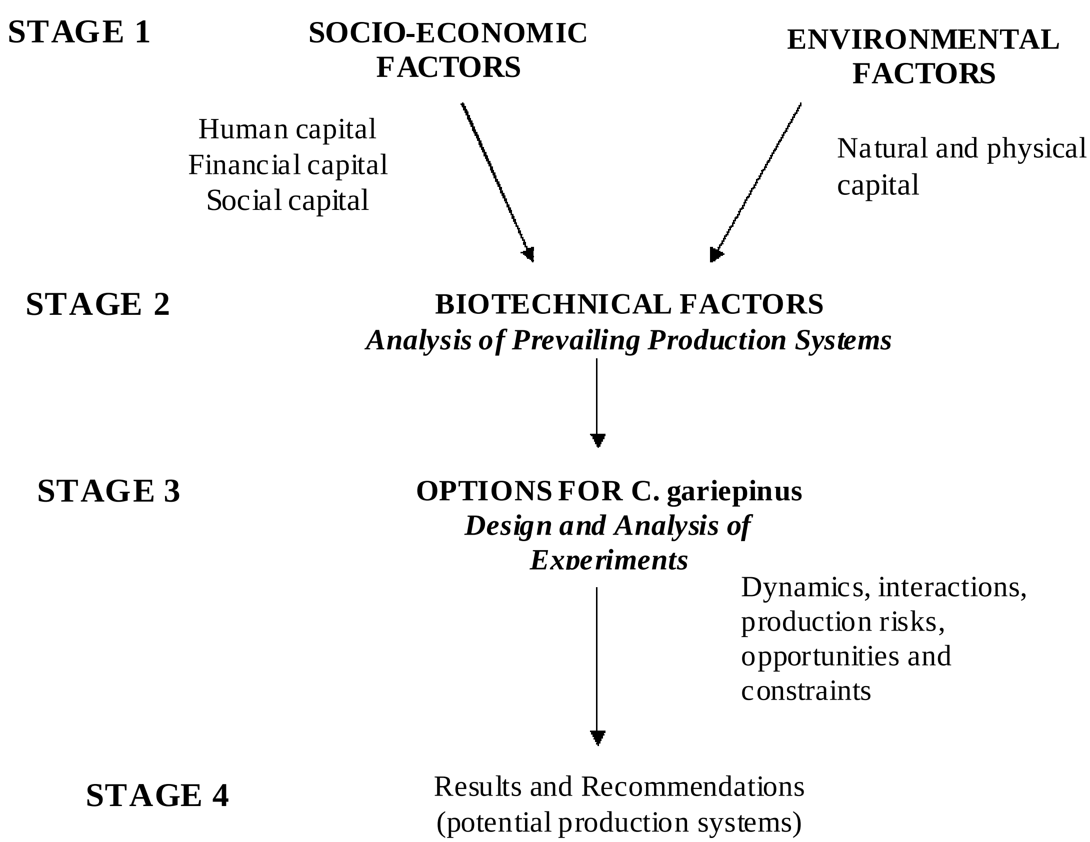

Figure 3.1. Methodological Framework

Rapid rural appraisal techniques were used to generate primary data on farmer status, current production practices and market options for *C. gariepinus* in the basin. Quantitative data to assess current or potential production was obtained through estimating inputs and yield from sampled farmers' ponds. On-station trials were used to generate more quantitative data on production possibilities of *C. gariepinus*. To assess impact of location, sample sites were selected based on agro-ecological zones within the Lake Victoria Basin. These were the Banana Millet Cotton (BMC), Intensive Banana Coffee Lake Shore (IBC) and Western Banana Coffee Cattle (WBC) farming systems (see appendix A).

RRA findings were augmented with quantitative production data from sub-set of participant farmers. PCA was then used to identify key variables in the production system, and to examine their inter-relationships and influence on current production trends (figure 3.1). The following stages were employed.

<u>Stage 1</u> Socio-economic data gathered from all fish-farmers in selected areas, using rapid appraisal techniques. This covered human capital (labour availability, skills, etc.), financial capital (ability to invest in aquacul economic goals), social capital (how they worked together, access to markets, etc.) an natural and physical capital (resources available from the natural environment, infrastructure, etc.). This was supplemented with more detailed information on financial capital from wealth ranking research, conducted on a sample of the farmers. Market surveys gave the necessary information for economic analysis.

Stage 2 Analysis of this data revealed that the agro-ecological zone was a key factor for all capitals. Quantitative data on pond production was therefore collected from a sample of fish farmers in each of the 3 zones. This data was supplemented with information from RRA with farmers (from stage 1) and from other key informants. Data

was then analysed using PCA, with contextual information from stage 1 being the key to interpreting the correlations.

Stage 3 Key correlations suggested the areas of most critical concern for further research (seed, feed), and the most promising species for polyculture (tilapia/catfish). On-station experiments were then designed and run.

Stage 4 Results of the experiments, together with the production data from stage 2, were analysed for feasibility and profitability using the infor ation and analysis from stage 1.

3.2. Survey approaches

The basic techniques used for data collection were sample surveys incorporating a variety of rapid appraisal tools and pond production trials. Sample surveys had different objectives and varied in design and data collection te hnique, depending on the sample frame and specific objectives (Table 3.1). This covered both producer and market/consumption issues. Alterations were made to standard sampling techniques where there were deficiencies in data on total target population sizes (Chatfield, 1995), to improve sampling efficiency and reduce bias to reflect the actual fish farmer population.

Table 3.1 Summary of Sampling Methods and Objectives

Source and Type of Data	Sample Unit	Sample Design	Tools Used	Objective/Relevance to Study
Farmers Qualitative	fish farm unit household	one-stage cluster design simple random	RRA wealth rankings	Resources for aquaculture, production and constraints
Farmers Quantitative	pond	simple random	Sampling ponds	use of inputs for fish production, production trends, costs of production
Fishmongers and Consumers Qualitative	markets	stratified simple random	RRA	data and parameters for economic analysis
Fishermen Qualitative & Quantitative	landing site	simple random	RRA	demand for bait and options for *C. gariepinus* production

The sampling procedures used in the surveys were condu ted as described by Barnett (2002). Sampling targets were based on proportions because there were no accurate figures for the population size in most cases. A sampling intensity of 20% in this case was considered sufficient.

3.2.1. One-stage cluster sampling

This was used as the sampling framework for the RRAs targe ng fish farming units. A cluster was defined by the sub-county, the main administrative unit within a District, with a typical population of 4-5,000 households. Once 20% of the sub-counties in a District were chosen by random sampling, all fish farmers in that sub-county were included in the target population. This was used as fish farmers were spread non-uniformly in districts. District fisheries staff also considered their records on fish farmer population as out-dated and largely inaccurate. They commonly faced constraints in accessing their clients, and so tended to visit or know only the farmers within easy access.

Consequently, upon selection of a sub-county, district records provided a guide to the number and location of an initial set of fish farmers. These and other persons in their villages were then asked if they knew of other fish farmers in their neighbourhood. These farmers were also visited. Consequently in some a sampling intensity of more than 20% of official records was obtained. The fact that this was higher than the target was ignored because it was assumed that spatial and person biases associated with district fish farmer records had been reduced in favour of increased sampling efficiency within the cluster. A total of 104 fish farming units (i.e. fish farming households or groups) were sampled out of an estimated 212 in the sample frame (appendix B).

Other advantages offered by one-stage cluster sampling included administrative convenience as each fisheries extension worker was responsible for specific sub-counties.

It also eased sample specification, improved access to the population and reduced sampling costs. Any loss in efficiency attributable t cluster sampling was assumed to be outweighed by reduction in sampling costs and greater sampling facility (Barnett, 2002).

3.2.2. Simple random sampling

From within the population generated by the cluster sampling (of sub-counties, 3.2.1), simple random sampling was used to develop two smaller sample sets, to generate data on fish farmers' relative wealth status and assess production levels. Sampling in both cases was based on the total number fish farmers' sampled in the RRA (see 3.2.1). In each case a minimum target of 20% of the population wa set, in consideration of time and resource limitations. Time limitations arose as a result of:

- The distances between villages with fish ponds in some areas.
- Time to complete the exercise particularly for wealth rankings in large villages and where ponds were poorly constructed or unkempt.
- The limited time available in a day for working with f rmers. It was not practically possible to make appointments. During late mornings and afternoons, most villagers would have gone off on their business and it ime to look for participants. For wealth rankings and sampling of farmer's ponds for production data, their participation and help was also required.

***Wealth rankings*:** Sampling for wealth ranking was done at village level Three persons per village participated in the exercise, one of whom was a fish farmer. A total of 50 villages were sampled and 238 fish farmers ranked (appendix B). The number of fish farmers was higher than the total sample population in **3.2.1,** above, as fish farming groups were considered as a single unit, but members were ranked independently. The number of persons ranked per village varied with village size and the number of household heads participants could identify. In the latter case, some bias may have resulted but useful comparative data were still obtained because of the independent participation of two other persons. (The extremely po , recent immigrants or landless could have been excluded by participants.)

***Production data*:** The sampling frame for production data was based on location rather than wealth stratification because RRA information indicated tha the agro-ecological zone was the key determinant variable of most other fa tors. Stratification could have been done by wealth status, but results from the wealth rankings indicated that wealth status was also significantly associated with location (Kruskal-Wallis Test: H = 45.7, DF = 4, P = 0.00). A total of 54 fish farm units and 69 onds were sampled from the initial sample (see appendix B).

3.2.3. Stratified random sampling

This was used to obtain data from consumer fish markets. Markets in the ricts are categorised administratively as major or minor. A total of 25 major and minor markets were sampled (appendix B). The two categories were not distinguished in the analysis, since the objective was just to establish basic information about fish marketing for w ich no literature exists (sizes of fish sold, market prefe ences for size and species, availability, prices, etc.). For the same reasons, the markets, rather than the population of fishmongers in a district, were used as the sampling f ame. Formal market studies would normally sample by reference to a frame of fish-sellers and consumers. However, no records exist of the number of informal traders operating in rural areas (often without stalls or any fixed place of work) and since the availability, prices and local preferences for fish would depend upon a market rather than on an individual trader within a market, there was no reason to spend time to independently est blish a sample frame of traders.

A total of 65 fish-sellers and 97 consumers were interviewed in the markets. Consumer sample size was not pre-determined in relation to the total district population N, for the reasons above. Consumers were interviewed within markets to verify information given by fishmongers, and it was therefore considered sufficient to interview only the consumers who came to purchase fish at the time of sampling. Results were not intended to be statistically extrapolated to represent the views of the district population *N*, but only to give an indication of what fish consumers preferred (appendix B).

3.3. Data management

3.3.1. Qualitative data

A variety of Rapid Rural Appraisal tools were used to generate data, after pre-testing on a randomly selected sample of 17 farmers from Kampala, Wakiso and Mpigi districts. A range of RRA tools were employed, including semi-structured interviews with fish- and non-fish-farmers, rankings, interviews with key informants, farm walks, discussion with farmers and mapping of farms (see appendix C). Of these, three tools were selected and refined for use in the rest of the study. These were selected on their ability to capture the desired information as quickly and precisely as possible.

Semi-structured interviews and discussions: The objective was to enable the researcher to generate information on local factors that affected farmers' production at farm level. This approach was opted for in recognition of the complexity of smallholder agriculture. (Semi-structured interviews guide the farmer to certain topics, but leave him/her to raise whichever issues are most appropriate: a closed questionnaire is useful for researching complex systems only after the key issues have been identified in a 'semi-structured' enquiry). Information was collected on key factors affecting the ability of farmers to engage in meaningful fish farming, as follows:

Socio-economic issues: farmers' objectives, sources of investment for aquaculture, knowledge and skills, species market potentials, costs of inputs.

Natural resource capacity: potential inputs locally available from farms or the natural environment, levels of availability, water sources and supply.

Bio-technical aspects: management practices, yields, quality of harvests, species stocked, production constraints.

Semi-structured interviews were considered most appropriate as they ensured that information covered the areas required, but without li iting dimensions of farmers' responses. This made it possible to take each farmer's case as important, appreciating the uniqueness of each situation. The checklists used with farmers, extension workers, district personnel and within the markets are included in appendix D.

Ranks and scores: Farmers, fishmongers and consumers were asked to rank or score species preferences and key constraints and give reasons for their choices (see appendix D for details). They had to prioritise only three or our choices. From the ranks and scores, it was possible to identify limiting factors concerning their overall farm management decisions regarding enterprise investment, availability and use, and marketing issues concerning fish species, form and size.

Key informants: Information was obtained from key informants through informal discussions and interviews. They included district and national fisheries personnel, managers of fish factories and NGO personnel in the ag icultural sector. They were used to obtain information affecting fish farming off the farm, to verify farmers' observations (as a form of triangulation) and to obtain a broader view of production and its constraints and potentials in the districts.

Wealth rankings: Three informants were asked to describe the categor ation of household wealth according to their own criteria. The names of all the household heads in the village were then written on small cards, with fish farming households indicated by the letter 'F', put in brackets beside the household h 's name. Each participant was then asked individually to group the cards according to their perceptions of the household's wealth, and the score was recorded at the back. Scores were represented as the percentage value of the ascribed wealth status from the total number of wealth groups identified (for example, a household put in the second wealthiest of five wealth groups was given a score of 0.4 or 40%). The average percentage of the three rankings was used for analysis. Participants were also asked why and how they made these categories.

3.3.2. Quantitative fish pond production data

The objective of obtaining quantitative production dat was to augment and verify inferences derived from the qualitative analysis. Thi data made it possible to translate observations made in section 3.3.1. into actual produc ion and returns..

Quantitative data was obtained from a subset of farmers sampled as already described (3.2). The selected farmers' ponds were sampled for t quantity of input, yield, production cycles and various pond characteristics (se endix E). Several difficulties were encountered in giving values to these variables. None of the farmers sampled kept any production records, or weighed their inputs. Characterising their management practices was also difficult as these varied significantly during the production cycle. Input quantities were therefore obtained by weighing the volumetric measures farmers used (i.e. bunches, heaps, mugs, basins, wheelbarrows r sackfuls) as recommended by Ashby (1986). Total net weights of inputs in kg/ha/yr e then derived from aggregate figures as given by farmers, based on estimated monthly input (Lightfoot *et al.*, 1994). Items which farmers did not measure, such as household waste, were given a dummy value of 1 if used as inputs and 0 if not. It was dif icult for farmers to estimate quantities of household waste used as availability was highly variable.

It was not possible to quantify yields by asking farme s about actual harvests, because many had never harvested and none kept any records of casional harvests. Fish yield was therefore estimated by sampling fish in the pond using a seine net and then multiplying the average weights by the original number of fish that farmers had stocked. It was not possible to obtain an accurate inventory of fish numbers in ponds, as this would have entailed draining them. It was therefore not possible to quantify effects of losses from predation and mortality or "gains" from reproduction or wild fish entering the pond. Instead, where ponds exhibited signs of having eproduction, i.e. where there were large numbers of small fish in the sample, it was assumed that their critical stocking capacity (CSC) had been attained if production periods were coming to one year. This was measured qualitatively with a dummy value.

Costs were also obtained for all inputs and in cases where farmers ad harvested and sold some fish before, the estimated average weights and farm-gate price were obtained. Feed and fertiliser inputs were analysed for dry matter, cr de protein and total nitrogen using proximate analysis, in order that comparisons of yield in relation to total input could be done between zones (Cacho, 1993; Ashby, 1986).

3.3.3. Data analysis of rapid appraisals

Only data from respondents with complete profiles was nalysed – 91 out the original total of 104. Incomplete data profiles were obtained where:

- the person(s) closely involved with the day-to-day pond management was not available at the time of the visit.
- the respondent was sensitive about giving information. Information which was sensitive included earnings, livestock owned or the number of their children .

***Qualitative data*:** The ordinal data obtained from the rapid appraisals was coded and analysed descriptively using cross-tabulation and the chi-square test of association with the statistical package MINITAB release 13.1® by Minitab Inc. This made it possible to examine relationships between two variables. The probability that there was an effect of one variable over another was considered significant at the level $\alpha = 0.05$. Ordinal data was analysed using the Kruskal-Wallis Test in MINITAB release 13.1® (appendix F). The availability of key inputs, fertiliser, pasture an arable wastes, cereal and grain residues and seed variation was qualitatively determined based on scores. The criteria used were:

- seasonal influence
- effect of the local farming system
- market influences
- competitive uses on farm
- whether or not a farmer had to pay cash for the input.

Maps: An array of qualitative and quantitative information was derived, indicating significant variation in availability of commonest pri ry fish farming inputs based on agro-ecological zones. This information was mapped, using GIS techniques, with ArcView 3.1 software (with positive scores for factors with a positive impact on availability, and negative scores for a negative impact on availability). Primary inputs for which maps were generated were: pasture and arable was e, cereal and grain residues, fertiliser (cow dung). A catfish demand and supply map was also generated using secondary data on pond sizes which gave farming intens ty, and hence potential supply per study district, and the number of registered boats on the lake shore to estimate the number of long line fishermen, and hence potential demand for bait..

***Quantitative data*:** Descriptive analyses were also done using MINITAB release 13.1®. Ranges were considered more appropriate in the study b cause most figures obtained were approximations. Furthermore quantities of some items such as livestock are never constant in reality depending on reproduction, survival an onsumption.

3.3.4. Multivariate data reduction

For PCA, fish farming systems were categorised according to the pecies farmed.. The description of variables was as follows (for details, table 3.2):

***a) State Variables*: -** direct physical inputs farmers put into their ponds su h as number of fish stocked, and amount of feed and fertiliser input. Data was obtained from farmer data, and pond sampling. Other than for seed, all measurements in the analysis were in kg/ha/year.

***b) Rate (management) Variables*:** were the regimes with which farmers applied their inputs, the flow of materials to the system, in both quantitative and qualitative terms. Where no records were available, qualitative values wer used, using dummy variables.

Table 3.2 Variables used in Principle Component Analysis

Variable	Units
State Variables	
Fish inputs	
O. niloticus, or C. gariepinus:	Stocking density of either O niloticus or *C. gariepinus* (no. ha^{-1})
O. niloticus and C. gariepinus:	Stocking density of *O. niloticus* and *C. gariepinus* (no. ha^{-1})
All fish types:	Stocking density of all fish species farmed (no. ha^{-1})
Feed/fertiliser inputs	
cow dung, chicken dropping; goat droppings other animal manure	kg/ha/yr
compost maize bran rice bran wheat bran	kg/ha/yr
termites fish meal fish intestines rumen content blood and abattoir waste	kg/ha/yr
cooked maize meal ("*posho*") millet flour cassava weeds cassava leaves yam (taro) leaves *Galisoga pariflora* ("*kafumbe* grass") sweet potato leaves	kg/ha/yr
household waste bread	kg/ha/yr
cotton seed cake sunflower seed cake	kg/ha/yr
organic input	kg/ha/yr
protein input	kg/ha/yr
nitrogen input	kg/ha/yr
Rate Variables	
area of farm	approx. ha?
area of pond	m^2
depth of pond	metre
age of seed	dummy (fingerlings = 1, young = 2, adult = 3)
fertilisation frequency	dummy (none = 0, weekly = 1, fortnightly = 2, several times a week = 3, monthly = 4, irregularly = 5)
fertilisation strategy	dummy (single = 1, mixed = 2)
feeding frequency	dummy (none = 0, daily = 1, weekly = 2, fortnightly = 3, several times a week = 4, monthly = 5, irregularly = 6)
feeding strategy	dummy (single = 1, mixed = 2)
culture period	months
Intrinsic variables	
age of farmer	approx. years
experience as fish farmer	approx. years
age of pond	approx. years
agro-ecological zone	dummy variable (BMC -FS = 1, MAIBC-FS = 2, WBC = 3)
wealth ranking	Scores
yield	kg/ha/yr

These included farm area, pond area, depth, number of nds operated, size of seed stocked, culture period, fertilisation and feeding strategy and frequency, CSC and number of cohorts in pond.

***c) Intrinsic Variables*:** factors that could not be changed or acquired at a gi n time by farmers. These related to the farmer's socio-economic profile and location, including agro-ecological zone (AEZ), age of farmer, relative wealth tatus of farmer, category of pond ownership (group or individual), farmer experienc , and age of ponds.

d) ***Estimated yield***: in kg/ha/year

For each farming system there were two models. Model 1 comprised the state variable only and Model 2 comprised the state, rate and intrinsic variables. Only variables with correlation coefficients of 0.20 or above were taken as significant (Veerina *et al*., 1999).

3.4. Production trials

3.4.1. Introduction

The choice of experiments for potential production sys ems was based on the conclusions of the results of section 3.3. (discussed in Chapters to 6) in relation to the three primary factors – socio-economic, environmental and bio-technical.

Socio-economic: The primary issue was the farmer's main objective for aquaculture, income. Hence factors affecting marketability, notably species, size and price were used to assess potential returns. Farmers and consumers both ranked tilapia (*Oreochromis niloticus*) as their preferred species. Among fish farmers *C. gariepinus* was ranked second, despite their knowing it had a higher market value and could attain a larger, more marketable, size more quickly. In their view, tilapia was tastier and more popular, and so more marketable. They also accounted for household preferences. Consideration was also given to costs and availability of inputs for the rity of farmers, in choosing feed and fertilizer inputs for the experiment.

Environmental: Cow dung and maize bran were the most widely used and ailable inputs in all zones. Maize bran was chosen as an input rather than pasture and arable wastes as it was easier to obtain adequate amounts for on-station experiments. For most farmers, local availability and accessibility of feed and fertilizer were also limited, and varied during the production cycle.

Bio-technical: Production was significantly limited by ponds attaining their critical standing crop. Results showed that critical standing crop was the greatest limiting factor influencing *O. niloticus* production. The high number of cohorts also showed that this was due to reproduction. Stocking rates were the second most important variable affecting production levels and trends.

The effect of farmers' management practices in response to production constraints was also taken into account. Thus, *O. niloticus-C. gariepinus* polyculture rather than *C. gariepinus* monoculture was chosen, with *O. niloticus* the primary species, as *O niloticus* is the predominant species in aquaculture in the basin and the preferred market species. Two experiments, one testing stocking densities and the other testing varying levels of feed and fertilizer were conducted. Ideally a complete factorial design should have been set up to test the effect of these variables with both and either species and at varied stocking ratios. However, in view of resource limitations, two experiments were run, based on most important constraints of stocking density and feed/fertilizer use. Figure 3.2 shows the pond layout, and the position of a dividing m, with potential effects (see below).

Experiment 1: The effect of stocking density on yield and returns of *O. niloticus* fed maize bran in earthen ponds fertilised with cow dung

Initially to be based on *O. niloticus-C. gariepinus* polyculture, this was run with only *O. niloticus*. because of seed constraints. The trial was conducted in twelve 600 m^2 earthen ponds. Four treatments, I, II, III and IV, tested eff s of stocking density at 1, 2, 3 and 4 fish/m^2 respectively. The experiment was run as a randomised ock design with six ponds on either side of a stream. Consequently there ere three blocks each running a replicate of the four treatments (figure 3.2). This enabled the detection of any effect of the stream on pond yields.

Ponds were stocked with *O. niloticus* fry averaging 1.00 g, over a period of four weeks due to constraints of seed availability, each block stocked over one to three days. Fish were fed maize bran at 5% of body weight per day except on the sampling day. All ponds were fertilised with 10 kg cow dung/100 m^2/week.

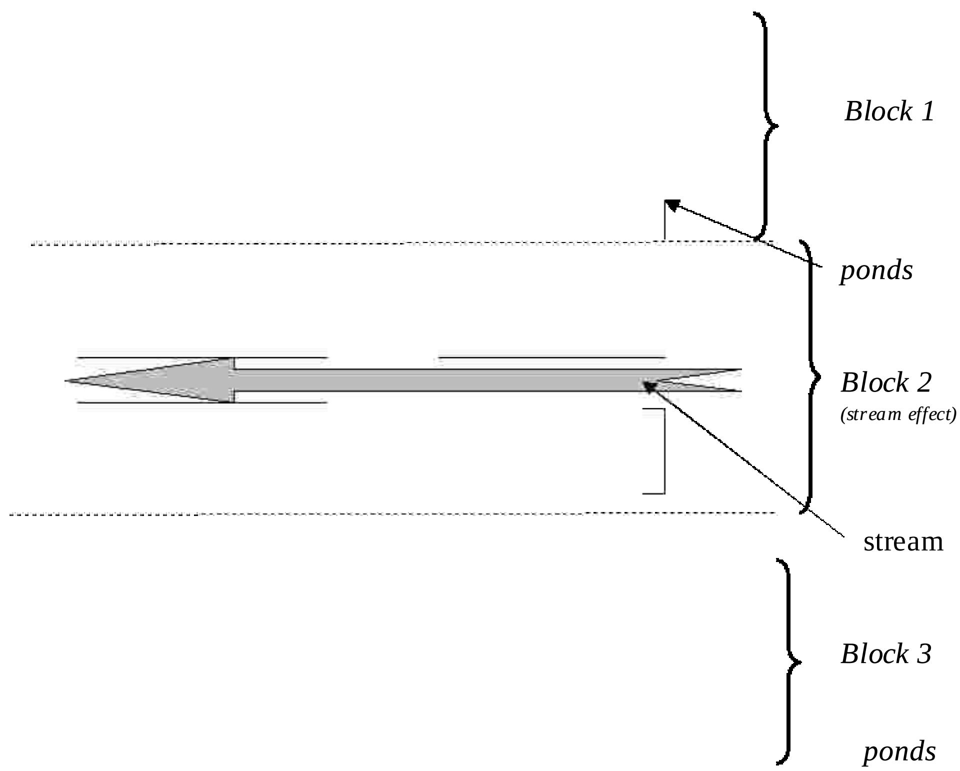

Figure 3.2: Experimental Pond Layout

Experiment 2: The effect of varying cow dung and maize bran input levels on pond yield and returns in *O. niloticus – C. gariepinus* polyculture.

This also used sixteen 600 m^2 earthen ponds in a randomised design. Six treatments tested effects of varying cow dung and maize bran input (table 3.3). The cow dung was substituted at a decreasing rate with maize bran. There were three replicates per treatment for treatments I to V, but one replicate for treatment VI due to limitations in the number of ponds. Hence the experimental design was unbalanced (Clarke, 1994).

Table 3.3: Description Of Treatments In Experiment 2

Treatment	Fertilisation Rate (Kg Cow Dung /Pond/Week)	Feeding Rate (Maize Bran % Body Weight)	Number Of Replicates
I	60	0	3
II	45	1	3
III	30	3	3
IV	15	5	3
V	0	satiation	3
VI	60	satiation	1

'Satiation' indicates that feed was given until the fish stopped feeding.

Ponds were stocked with *O. niloticus* and *C. gariepinus* at the rate of 3 fish/m^2 and at a stocking ratio of 3 *O. niloticus* to 1 *C. gariepinus*. Fry were stocked from a week after filling ponds over a period of nine weeks, also due to seed supply limitations. One replicate of every treatment was stocked at each time. The average weight of *O. niloticus* at stocking was 1.5g and of *C. gariepinus* 5.0g.

3.4.3. Pond management

Prior to stocking, the ponds were cleared, drained, dredged and dried. Half the ponds had been unused for several years prior to the experiment d were under bush. Pond sediment was therefore sampled to a depth of 20cm prior to stocking, because previous pond operations affect pond fertility and production (Boyd and Bowman, 1997). Samples were analysed for pH, % organic matter, total N (%), total P (%), available P (mg/l), K (mg/100g), Na (mg/100g), Ca (mg/100g), % sand, % clay, % silt by Makerere University, Faculty of Agriculture and Kawanda Agricultural Research Institute soil laboratories. The difference in values for all parameters between ponds was found to be small, so all ponds received the same base treatment with slaked (builder's) lime ($Ca(OH)_2$) at the rate of 0.08 kg/m^2, and 10kg /100m^2 of cow dung (appendix H).

In both experiments feed (maize bran) was broadcast. he daily feed requirement was divided in half and fed at 10.00 and 16.00 hours. The maize bran was tested for % dry matter, % crude protein, and % crude fibre using proximate analyses (AOAC, 1990). Samples were taken and analysed at the start, middle and end of each experiment by Makerere University, Faculty of Veterinary Medicine, Nutrition laboratory.

Fresh cow dung was obtained from a zero-grazing unit once every 2 to 3 weeks. It was stored outdoors in a heap both at source and on-station. Samples of cow dung were taken and analysed at the start, middle and end of each expe for pH, total N (%), total P (%) and dry matter by Makerere University, Faculty of iculture and Kawanda Agricultural Research Institute soil laboratories. Bot laboratories used procedures recommended by AOAC (1990).

3.4.4. System data collection and analysis

Fish performance

Ponds were sampled for growth once every three weeks by seining. The sample size from each pond was determined according to Knud-Hansen, (1997), (appendix I). Parameters obtained were average batch weight (g) and i ividual total length (cm). Weights were obtained to the nearest hundredth gram using an Adams balance, model FEL 41005. Total lengths were obtained to the nearest mm with a standard 50 cm-ruler. The amount of feed was calculated after each sampling eadjust to the desired level as described for each experiment. Feed at each consequent feeding was measured to the nearest gram with an Adams balance, model FEL 41005.

Environmental parameters

Water quality was analysed in order to ascertain its suitability for fish growth and to explain variances in yield that may not be attributable to treatment. Ponds were sampled every 10 days for pH, temperature, dissolved oxygen, and Secchi disc depth, as outlined in table 3. In the first experiment a Wagtech portala model 5000 was used for water quality analysis until the 5th sampling point (14 weeks) when the apparatus became faulty. In the second experiment these parameters were obtained as described in table 3.4. Water sampling was done between 7.30 hours and 9.00 hours at each sampling.

Table 3.4 Methodology for Fortnightly Water Quality Analysis

Parameter	Measurement	Units	Method
pH	in situ	pH	Corning pH meter,
Temperature	in situ	^{o}C	Corning DO meter, model 9071
Oxygen	in situ	mg/l	Corning DO meter, model 9071
Conductivity	in situ		Conductivity meter, Wagtech
Secchi depth	in situ	cm	Secchi disc

Due to difficulties with field testing equipment, backup samples were also analysed intermittently by an independent laboratory. These were obtained and sent for analyses once during experiment 1 and three times during experi t 2 to the limnology laboratory, Fisheries Research Institute. In experiment 2 this was one at the start, middle and end of the experiment.

Other issues

Other management and environmental factors could have affected the trials:.

Frequent leakage from a number of ponds resulted in loss of fish. This was accounted for by use of dummy variables equalling the sum of lea oted between sampling. Water depth was also taken in the morning and evening to assess the level of leakage.

There were periods when manure and feed was not applied to the ponds.

Predation by birds and otters occurred in some of the ponds.

As far as possible, potential effects were noted, impa estimated, and considered in subsequent analyses.

Biological data analysis

Differences in levels of production between treatments was compared using analysis of variance (ANOVA) followed Tukey's means comparison tes using the statistical package MINITAB release 13.1® by Minitab Inc. In Experiment 1, ANOVA was done using the General Linear Model to assess the effect of reatment and blocks on yield. In experiment 2, the General Linear Model was used instead of the two-way ANOVA to test for treatment and species effect on production because the experimental design was unbalanced. Means were considered significantly different at $\alpha = 0.05$. The effect of environmental and management factors on production was analysed using factor analysis (Milstein and Hulata, 1993; Milstein, 1993).

Economic Analysis

Experiments

Parameters, adopted from Shang (1990), to assess productivity of input use and economic returns are detailed in Box 3.1. Initial investment costs, notably land and tools, were not included as farmers converted, rather than purchased, land, and did not purchase tools specifically for aquaculture. The only capital cost (as cash) most farmers had invested was for pond construction, where opportunity costs were more relevant. 'Returns to land' were therefore viewed as construction costs and interest on construction cost.

In view of the cash flow structure of most rural farmers, their financial/capital capability and their aquaculture production characteristics with espect to what are commonly considered 'variable costs', were counted in analysing returns to investment.

Box 3.1 Parameters used to Analyse Productivity and Economic Returns

Productivity of Inputs

1. $$productivity\ of\ land\ (kg/m^2) = \frac{amount\ fish\ produced\ (kg)}{total\ pond\ area\ (m^2)}$$

2. $$productivity\ of\ labour\ (kg/md) = \frac{amount\ fish\ produced\ (kg)}{amount\ labour\ used\ (md)}$$

3. $$productivity\ of\ fertiliser (kg/kg) = \frac{amount\ fish\ produced\ (kg)}{amount\ cow\ dung\ used\ (kg)}$$

4. $$feed\ conversion (kg/kg) = \frac{amount\ feed\ (kg)}{amount\ fish\ harvested\ (kg)}$$

Economic Indicators

5. $$profit\ (UShs.) = gross\ income - total\ operational\ \mathrm{cos}ts$$

6. $$profit\ (exclusive\ of\ labour\ \mathrm{cos}ts)\ (UShs) = gross\ income - [total\ operational\ \mathrm{cos}ts - total\ labour\ \mathrm{cos}t]$$

7. $$returns\ to\ investment\ (farmer's\ view) = \frac{profit\ (UShs)}{total\ seed\ \mathrm{cos}t\ (UShs)}$$

8. $$returns\ to\ investment\ (economist's\ view) = \frac{profit\ (UShs)}{[total\ operational\ \mathrm{cos}t + total\ capital\ \mathrm{cos}t]\ (UShs)}$$

9. $$returns\ to\ labour\ (UShs./wd) = \frac{[profit - total\ \mathrm{cos}t\ labour](UShs)}{amount\ labour\ (wd)}$$

10. $$returns\ to\ land\ (UShs./m^2) = \frac{[profit - [\mathrm{cos}t\ construction + \mathrm{int}erest\ construction]](UShs)}{total\ pond\ area (m^2)}$$

11. $$\mathrm{cos}t\ of\ fish\ produced\ (UShs/kg) = \frac{total\ operational\ \mathrm{cos}ts\ (UShs)}{total\ yield\ (kg)}$$

12. $$break-even\ production\ (kg) = \frac{total\ operational\ \mathrm{costs}\ (UShs.)}{unit\ \mathrm{cost}\ of\ fish\ (UShs./kg)}$$

13. $$ratio\ of\ profit\ to\ operating\ \mathrm{cost} = \frac{profit}{total\ operating\ \mathrm{costs}}$$

According to Jolly and Clonts (1993), the distinction between capital costs and total variable costs is not always clear and application varies depending on the period of production. Most farmers sampled had only had one cy le of production despite their ponds having been in production for long periods. Thus, items such as seed or feed had not yet become variable costs as no re-investment out of returns into another production cycle had been done to ensure continuation of the enterprise. Furthermore, if one had procured a loan these costs would have to be recovered from the operation with interest.

Returns to investment were analysed in two ways. Standard "returns t investment" is defined as the economist's view. However, the farmer's view of a return is often different (see section **7.4.5**). Farmers often placed no monetary value on land, implements or their labour for aquaculture. In their terms, it was physical outlay of cash (their conscious monetary investment) that determined ether or not they could engage in aquaculture. This was mainly related to procurement of seed.

All analyses were based on actual costs for inputs, units of sale plus average wholesale fish prices as given by fish traders (section 3.3). Where inputs were obtained free, a shadow price was used, based on assumptions mentioned table 3.5, in order that they reflect farmers' real costs.

Table 3.5 Considerations in Cost Allocation and Economic Analys s

Parameter	Assumptions
yield	In view of leakages and the fact that realistically yi lds of 100% are hardly achieved. Calculations were done based on yields of 80% and 60% of total number of fish stocked.
Cost of capital	An interest rate of 20% was used based on average interest rates of commercial banks in Uganda in 2001/2002.
Cost of labour	The cost of labour 750/= was included in all calculati ns as an opportunity cost. The assumption was that the lowest daily wage in rural areas was about UShs. 1,000/- per man-day.
Cost of Seed	UShs. 25/= was added to current costs to cater for far rs transport costs. The assumption was based on farmers average pond size (200m^2) at a stocking density of 2 fish/m^2 and average return bus fare of UShs 15,000/= from the study areas to Kajjansi. The range taken for sensitivity analysis was determined by the unit prices farmers paid for seed, irrespective of source.
Feed price	It also based on the price ranges farmers mentioned they paid for maize br . A shadow price of UShs. 30/=/kg was considered in the event that farmers may have had a source from which they did not have to pay.
Cow dung	A minimum shadow price of UShs. 30/= /kg was set because of the alternative uses of animal manure by farmers for production of cash crops. The value was based on the cost of N_2 in 25 kg bag of NPK 20:10:10 that cost UShs. 25,000/=
Fish prices	The prices ranges given to fish were based on the pric s obtained from markets. The prices used in the study were those from the rural areas and olesale prices as these were considered prices an ordinary person in a rural area could afford to pay. The assumption was that a farmer should be able to sell their fish locally first, given the constraints in marketing channels.

Partial budgets were done based on costs and returns i order to examine the cost-benefits (at experimental cost) of farmers adopting increased s ocking densities in *O. niloticus* mono-culture and an increase and/or reduction in fertiliser and feed i levels in *O. niloticus* – *C. gariepinus* farming.

Sensitivity Analysis

Sensitivity analysis was done to examine the cost and roduction limits within which experimental production would be economically viable (Pannell, 1997; Herrero *et al*., 1999). When analysing the effect of a selected paramet r on economic indicators, the other parameters were kept constant (table 3.7) (Petersen *et al*., 2002). The parameters were then discussed, based on their effects on the listed economic indicators.

Table 3.6 Parameters and Economic Indicators used in Sensitivity Analysis

Parameter Used In Sensitivity Analysis	Economic Indicators Tested
Biological	profit
percent yield	profit excluding labour
percent marketable size	returns to investment, farmers
Economic	returns to investment, economist
construction costs	returns to labour
cost maize bran	returns to land
cost cow dung	break-even price
cost labour	break-even production
cost capital	net profit:operating cost
price fish	receipts per fish: receipt per kg

Table 3.7 Values Kept Constant During Sensitivity Analysis of a Parameter

Parameter	Constant Value (UShs)
Marketable yield (%)	80
Marketable size (%)	80
Construction costs (UShs/m^2)	250
Cost of capital (%)	20
Seed cost (UShs/fish)	
O. niloticus	75
C. gariepinus	325
Feed cost (UShs/kg)	100
Manure cost (UShs/kg)	30
Price of fish, weight (UShs/kg)	
O. niloticus	1,200
C. gariepinus	2,000
Price of fish, size (UShs/fish)	
O. niloticus, small	300
C. gariepinus, small	1,000
O. niloticus, medium	700
C. gariepinus, medium	2,000

3.5. *C. gariepinus* seed demand and supply

3.5.1. Introduction

The initial objective was to assess factors currently ffecting supply and demand. However, in discussions with Fisheries Officers and traders, it became clear that there was a demand for *C. gariepinus* as bait. Demand was estimated using the quantitative/survey techniques already described focus ng on fishermen/bait traders to ascertain demand and possible opportunities for fish farming.

3.5.2. Demand

Seed

Potential demand for catfish seed by farmers was projected based on secondary data from District Fisheries Offices (DFOs). Where not possible, records were consulted from the Ministry of Agriculture on pond numbers and sizes within the basin, but unfortunately, the most recent data available was for 1997. Rapid appraisals were used to augment the data.

The average amount of *C. gariepinus* seed required per annum was estimated from scenarios described in table 3.8 below with respect to total pond area in the basin. It was assumed that farmers had one production cycle per year.

$$14. \qquad \textit{annual potential.seed demand } (S) = \frac{\sum_{n=1}^{n=9}[P \times SR \times SD]}{\sum n}$$

Where, P = total pond area in basin (m^2)
SR = stocking ratio (*O. niloticus*: *C. gariepinus*)
SD = stocking density (no. fish/m^2)
n = scenario

Table 3.8 Scenarios used in estimation of *C. gariepinus* seed demand

Scenario	Stocking Ratio	Stocking density (fish/m^2)
1	3[a]	1
2	3[a]	2
3	3[a]	3
4	5[a]	1
5	5[a]	2
6	5[a]	3
7	0[b]	1
8	0[b]	2
9	0[b]	3

[a] Adapted from de Graaf *et al*., 1996.
[b] Refers to *C. gariepinus* monoculture.

Bait

Random sampling of bait usage was done as described in section 3.3. The sampling frame was based on the number of landing sites on the shores of Lake Victoria in Busia, Bugiri and Wakiso districts. Sampling intensity was 20% of the total number of landing sites per district.

A total of 184 fishermen and 45 dealers in fish bait were interviewed. The number of fishermen interviewed was determined by the number that came to the landing site that day, irrespective of where they were normally based. Fishermen and traders were asked to estimate demand and supply on a weekly basis. Aggregate figures were used because none of the fishermen sampled kept records (appendix J).

The annual demand for *C. gariepinus* as bait was estimated using different scenarios based on the sum of traders monthly requirement. It was calculated as described below (see table 3.9).

15 $$annual\ bait\ demand\ (B) = \frac{\sum_{M=1}^{M=4}\sum_{S=A}^{S=C}\left(\sum_{n=1}^{n=12} b\right)}{\sum M \sum S}$$.

Where: M = model
S = scenario
b = traders monthly requirement
n = months of the year

16. $$traders\ monthly\ requirment\ (b) = \frac{L}{S} \times \sum t$$

Where: L = number of registered long lines in Lake Victoria (MAAIF, 2000),
S = scenario
t = proportion of traders requiring a certain amount o ait (based on survey results)

Assumptions: Bait required per month based on weekly demand. However weekly d mand was not multiplied by four because medians/averages were used and it was assumed the variations were likely to be great either above or below the means as there were no accurate records.

Table 3.9 Scenarios used to estimate *C. gariepinus* annual bait demand

Model[a]		Scenario		
Model No.	**Characteristics**	**A (10 lines/fisherman)**	**B (20 lines/fisherman)**	**C (30 lines/fisherman)**
1	3 fishermen/trader			
2	8 fishermen/trader			
3	15 fishermen/trader			
4	Estimated no. traders			

[a] Based on findings from survey.

3.5.3. Production and Supply

The supply of *C. gariepinus* was based on production records from Sunfish Farm Ltd., in Kajjansi, the only commercial hatchery producing *C. gariepinus*. Data was also obtained to assess the potential of farming *C. gariepinus* as bait. It included:

i. size and age of fry at stocking for growth to fingerlings in ponds

ii. feeding regimes

iii. time to minimum bait size recommended by fishermen and traders in fish bait

iv. stocking densities

v. costs of feed and manure

Economic analyses on potential of bait production as a farm enterprise were assessed using hatchery costs of production as described in section 3.4 above.

Chapter 8 draws out the implications of these findings in as far as they affect the potential of *C. gariepinus* farming for smallholder farmers.

CHAPTER 4

Socio-economic factors affecting fish farming in the Lake Victoria Basin

4.1. Introduction

This chapter analyses the potential for farming indigenous species based on a qualitative analysis of farmers' socio-economic conditions in relation to fish farming and lo al market potential. Survey techniques are summarised in the previous chapter.

4.2. Farmers and Farm Profiles Characteristics of the Fish Farming Unit

Structure and Size

Of the 91 fish farming units sampled, 67% were owned and managed by individual households and 33% by fish farming groups. Households were regar ed as dependent family units living within a homestead, and fish farming groups as a set o independent individuals or family units. The proportion of households and groups varied between agro-ecological zones and districts (Chi-Square P-Values 0.01 and 0.04 respectively). There were proportionately more groups (*N* = 30) in the IBC Farming System (57%) than within the BMC (30%) and WBC Farming Systems (13%). The proportion of groups to households was higher at th level within Bugiri (50%), Kampala (46%) and Wakiso (46%) districts.

Responses from key informants and farmers indicated that these differences were associated with constraints farmers faced in accessing land, capital, labour, extension services and other inputs for fish farming. Groups within the IBC Farming System were predominantly made up of the wives of low-income earners who were often unemployed. Such groups within Kampa a district had 'urban welfare' connotations because urban agricultural services were offered through the District's welfare department, rather than the Agricultural department as in up-country districts (Nyamutale *pers. comm.*). Wives of low income earners were encouraged to form groups through which they could pool resources to engage in income generating activities to supplement household income (and the nutritional status of their children). Together, they were able to acquire both inputs (notably feed, fertil ser and seed) and land for fish farming. As groups, they were more likely to be allowed to use unused land for fish production, belonging either to members of their communities (who often also became members) or to the local authority. Forming groups also made it easier for such women to ain extension services or financial support from NGOs or local government.

Within the BMC Farming System, farming groups were formed to improve ccess to extension services or to obtain financial support from NGO or local government developmental programmes. Within Bugiri district "groups" were often created only because access to services was conditional upon being a "group", though they were sometimes composed of "members" who were actually all from the same family. Such "groups" were considered as household units in this study. Fish farming groups in the zone were more commonly formed as a result of services offered by neighbours or friends in cases where farmers were short of labour for pond construction or inputs and the cash to obtain them. The neighbours and friends who helped were offered a share in the proceeds.

Sizes of fish farming units were highly variable (see ble 4.1). Household sizes appeared to be larger within the BMC Farming System than within the other two farming systems. Group sizes on the other hand were generally larger within the IBC Farming System.

Table 4.1 Fish Farming Unit Size by Agro-Ecological Zones

Fish Farming Unit	no. of respondents (N)	Mean (no. of persons)	Minimum (no. of persons)	Median (no. of persons)	Maximum (no. of persons)	Standard Deviation (no. of persons)
Household						
BMC	13	17.2	6	14.0	42	10.1
WBC	24	10.1	1	9.5	22	5.1
IBC	15	11.1	5	10.0	20	5.1
Overall	52	12.3	1	10.0	19	7.3
Group						
BMC	8	27.6	10	19.0	60	21.0
WBC	4	18.5	6	9.0	50	21.1
IBC	12	28.3	10	22.5	58	17.1
Overall	25	18.4	6	18.4	60	18.4

It was difficult to get reliable information about hou ehold sizes in Wakiso District, as many people, particularly older women, were cautious about giving details to strangers[2]. Difficulties in getting correct information about group size was attributable to the dynamic nature of groups, and some respondents were not sure o the actual numbers of their members, where new people had joined or old ones left. The sizes of families and groups where numbers were regarded as probably being incorrect were not recorded in the study.

Heads of households

Most fish farming units sampled (*N* = 87) were headed by men (87%). However, the proportion of male to female headed units depended on he structure of the farming unit and their location within agro-ecological zones (Chi-Square P-Values 0.00 and 0.03 respectively), as shown in Table 4.2 below.

Table 4.2. Percentage of units owned by women, by structure of unit and AEZ.

	BMC	WBC	IBC
HH units	0%	4%	14%
Group units	20%	0%	45%

[2] According to the 2002 census, the average household si e is 5-6: this could indicate that fish farming households have larger households than average, e.g. because it is an activit only carried out by established families with many children, or because respondents are understanding the term household in a slightly different way to UBoS.

Women were far more likely to be the heads of fish-farming units (whether group or household units) in the central IBC Farming System, and more likely to head group units than household units in both the Eastern and Central zones. (There was only one female headed unit in the WBC Farming System). The apparent absence of household fish farming units headed by women in the Eastern BMC Farming System, may in part be because traditionally all farming is run as a family enterprise in the East, where it is rare for women to have their own fields. This does not necessarily indicate that women were not involved in managing any units. However a full gender analysis of fish farming was beyond the s e of this study.

Respondents and key informants noted that there were p ortionately more female headed fish farming units in the IBC Farming System because of its urban and peri-urban nature. Consequently, there were more attractive economic oppo unities for men, and a greater demand on them to work for immediate cash-income rather than engage in small-scale agricultural groups. On the other hand in the BMC Farming System where the agricultural sector was the major source of employment, fish farmer groups were mostly mixed sex comprising young adults.

Wealth Status

Fish farmers were on the whole ranked among the wealthier members of their communities. However, this masks a more complex picture, where the wealth status among fish farmers varied according to their location within agro-ecological zones and districts, the sex of the unit's head and the structure of the farming unit (table 4.3). Fish farmers within the IBC Farming System (notably Kampala district) were ranked among the poor as opposed to fish farmers in the other zones. Women fish farmers were r ted as being poorer than their male counterparts. Household heads who were members of a fish farming group were rated as being poorer than those whose households farmed fish independently.

Various criteria were used by participants to assess wealth status. The main criteria used were people's additional sources of income; age and physica ability; ownership of livestock; ownership of land; to what extent farmers engaged in cash cropping; the nature of housing; education; and family size and structure (e.g. female headed households). These criteria were not used uniformly across the different agro-ecological zones. The criteria used in different farming systems are listed in full in appendix K.

Table 4.3 Effects of Location, Farm Unit Structure, Sex and Age on Wealth Ranks

Categories used to Compare Ranks among Fish Farmers	N[a]	Median Rank	Geometric Average Wealth Rank Fish farmer	Lowest Rank (wealthiest)	Highest Rank (poorest)	Kruskall-Wallis Test, P-Value
Agro-ecological zone						**0.00**
BMC	34	41	46	16	88	
WBC	47	33	46	17	100	
IBC	158	67	66	15	100	
District						**0.00**
Bugiri	13	37	36	16	56	
Busia	21	47	51	19	88	
Kampala	96	67	72	33	100	
Wakiso	62	60	56	15	100	
Ntungamo	47	33	46	17	100	
Farm Unit Structure						
Household	75	33	43	15	100	**0.00**
Group	164	67	66	16	100	
Sex						
Male	75	50	57	17	100	
Female	65	67	72	33	100	
Age Group						**0.40**
up to 25 years	1	67	67	67	67	
26-35 years	2	70	70	39	100	
36-35 years	9	33	42	15	67	
46-55 years	8	34	39	16	80	
+56 years	11	33	40	20	80	

[a]The number of farmers from whom data was obtained and analysed in the respective categories

4.3. Socio-economic assets and aquaculture

4.3.1. Objectives for aquaculture

The primary objectives that fish farming units had for aquaculture were income and household consumption. Income was considered most important by 71% of 85 res ondents. Household consumption was usually (65%) the second most important objective. However only 16% and 11% of units had the single objectives of income and hold food supply respectively, while 62% cited both objectives. Fish farmers cited income and household consumption as major objectives irrespective of their wealth ratings, location, age group or structure of fish farming unit. Other multiple objectives included hous hold consumption and training by 2% of units, and income and training by 9% of units. (This latter was cited by fish farming groups rather than household units). In Ntungamo district (WBC Fish Farming System), fish farmers who had no livestock hoped that through fish farming, they would eventually become cattle owners .

4.3.2. Species choice

Farmers were asked to list three species in order of p rence for aquaculture, irrespective of whether they were currently farmed or only obtained fr he wild. The most preferred were tilapias (*O. niloticus* is the most preferred), *B. docmac* and *C. gariepinus* (see table 4.4).

Table 4.4 Farmers' preferences for potential species for aquaculture

Fish Species	Farmers Rank 1 (%, *N* = 68)	Farmers Rank 2 (%, *N* = 65)	Farmers Rank 3 (%, *N* = 57)
Tilapia	40	45	19
C. gariepinus	20	39	16
L. victorianus	2	4	4
B. docmac	27	5	2
C. carpio	6	2	4
L. niloticus	0	2	0
Any	2	6	56

Note: Not all farmers had a second or third choice of species, hence *N* is not constant.

The reasons for species preferences in order of import ce were: family/local tastes; market potential; familiarity of the species; ability to grow to large sizes and reproduce in ponds. The potential growth rates and ability to attain preferred market size were important factors in the choice of *C. gariepinus* and *B. docmac*. The fact that tilapia have a high reproductive rate was not brought up as a major constraint in its choice. More farmers viewed this as positive, in that they would have many fish and not need to buy new stock. Among the negative attributes of *C. gariepinus* mentioned was the fact that it burrowed. This was a major p of concern among the farmers in Bugiri district whose fish ponds were a ong their rice paddies. However, its size at harvest, growth rate and marketability appeared to outweigh this negative attribute in the area, thus *C. gariepinus* maintained its second place. There was no significan difference between rankings and reasons for choice across agro-ecological zones.

4.3.3. Source of investment for aquaculture

The primary sources of investment capital for fish farming for 74% of fish farming units were cash and non-cash capital from their farms. Only 21% of fish farmers sourced their investment capital from off-farm earnings while 6% farmers used both on-farm and off-farm sources. There was no significant association between a farmer's investment sour or aquaculture and the fish farm unit's structure or location.

Most farmers (74%) did not consider financial capital s a major constraint. Among those who did however, 67% were from within the IBC Farming System and 33% from the WBC Farming System. None of the farmers within the BMC Farming system mentioned finance as among their major constraints (Chi-Square P-Value = 0.00). This was associated with the fact that in the IBC Farming System more hired labour was used for pond construction and ma agement and proportionately more of the fish farmers purchased some inputs.

Some farmers (21%) mentioned access to nets as a constraint. Of these, 89% were from the IBC Farming System and 11% from the WBC Farming System (Chi-Square P-Value = 0.00). In most districts, the District Fisheries Office was t source of seine nets. Farmers in the IBC Farming System were also able to access nets from the uaculture station at Kajjansi because of its proximity. In the BMC Farming System farmers also borrowed gill nets from fishermen. A couple of farmers had improvised materials in the WBC Farming System for harvesting fish. One farmer stitched up old gunny bags in the form of a seine net, made holes in it and used it to fish his ponds. The other fed stock from a perforated tin that he would pull out when the family wanted fish.

Labour

The family was the primary source of labour for most units, both for pond construction and management. Labour availability for aquaculture was influenced by the structure of farming unit, wealth status, location, age of farmer and the farmer's alternative livelihood options.

Pond construction

Fifty percent of farming units had constructed their p th labour sourced from within the unit and 42% with hired labour. Nine percent had used both hired and their own labour to construct ponds. The source of labour for constructio aried significantly depending on structure of fish farming unit at the 10% level (Chi-Square P-Value = 0.07). Among the household units, 41% used family labour and 49% hired labour, the remainder using both. However, 67% of fish farming groups had constructed ponds themselves compared to 27% that had hired labour, and 7% that had used both. Although the difference is not significant at 5% level, it makes sense that groups, who often come together because they lack labour on their own, should use more of their own labour. Poorer fish farming households depended more on family than hired labour for pond construction, 60% doing so, compared to 41% for the middle group and 36% for the wealthiest, of whom 56% had hired labour to construct ponds.

Costs of pond construction varied enormously. Forty-two of respondents (N = 64) had not spent any cash on pond construction: 44% had spent up to UShs. 1,500/= per m^2, 5% between UShs. 1,500-3,000/= per m^2 and 9% had spent above UShs. 3,000/= per m^2. Table 4.5 shows the characteristic cost ranges of pond construction costs as estimated by farmers.

Table 4.5 factors influencing amount farmers spent on labour for pond construction

Factor	No. of Respondents	No. Respondents	Mean (USh/m^2)	Minimum (USh/m^2)	Maximum (USh/m^2)
Agroecological zone					
BMC	15	8	802	200	4,037
WBC	25	5	1,071	80	5,875
IBC	24	14	1,141	29	4,100
Overall	64	37	1,030	29	5,875
Farm unit					
household	40		1,031	80	1,158
group	24		1,017	29	1,224

Data from RRAs

Pond management

Significantly more family labour was used for pond man nt than construction (Chi-Square P-Value = 0.00). Most labour used was obtained from within the farming unit irrespective o farmer's location, age group and farm unit structure. Of the total number sampled (N = 90), 71% relied on family labour, 13% on hired labour and 16% on both hired and family labour. While no significant P-Value was obtained, results indicated that the least amount of family labour was used amongst the wealthiest farmers for pond management, which is as one would expect.

Table 4.6 Effect of socio-economic factors on amount farmers spent on labour for pond management

Factor	No. of Respondents	No. of Respondents	Mean (Ush/month)	Minimum (Ush/month)	Maximum (Ush/month)
Agroecological Zone					
BMC	17	1	20,000	20,000	20,000
WBC	26	3	29,667	5,000	54,000
IBC	22	5	42,000	15,000	100,000
Overall	65	9	35,444	5,000	100,000
Farm unit					
household	42	5	40,800	5,000	100,000
group	23	4	28,750	20,000	45,000
Least wealthy	4	0	0	0	0

Data from RRAs

Forty-four percent (44%) of the wealthiest farming household units depended on family labour compared to 71% of the households in the middle wealth group and all households in the least wealthy group.

The view of most fish farmers (89%), irrespective of t ocation, wealth status, age group or the structure of the fish farming unit, was that labour availabili a critical constraint. However, some observations indicated that labour was i deed a constraint. For example, it took more than a year to construct ponds, particularly for eholds depending on family labour. Where households had older school going children, much of the construction was done during dry-season school holidays. Consequently, some farmers would build and stock a series of small ponds with the intention of merging them later, in order to derive output rather than letting the land lie idle over long periods during which it might become overgrown. Among groups, more of the women's groups hired labour for construction, depending on how difficult the site was. In mixed sex groups, men often did the heavy work. Also, it was observed that during the rainy (growing) seasons ponds became less w managed among both households and groups. This was because farmers diverted their attention to their fields and had less time for fish farming. Indications were that the opportunity cost for labour was high.

4.3.4. Knowledge

Fish farming experience among the units sampled varied m 3 months to 16 years, averaging 2.4 years. Twenty-five percent (25%) had farmed fish for less than one year, 56% for 1 to 3 years and 19% for more than 3 years. More of the new rmers were from the BMC and IBC Farming Systems (Chi-Square P-Value = 0.00). In the WBC Farming System, more fish farmers had farmed fish for at least 3 years.

Nevertheless, more farmers in the IBC Farming System considered their knowledge to be adequate compared to the fish farmers in the other two zones (Chi-Square P-Value = 0.00). This was attributed to the fact that the aquaculture s ation was within their zone. Station records confirmed that most of the farmers who visited the quaculture station (individually or as organised study groups with their local extension s aff or schools) were from the IBC Farming System. A number of the farmers who had farmed fish for several years mentioned they had learnt some things out of experience, notably what forage fish most preferred to eat.

4.3.5. Security

Most fish farmers (91%) did not consider security a co traint. However, within the BMC Farming System, after neighbours realised some farmers farming *O. niloticus-C. gariepinus* had good-sized fish, the incidence of theft from fish ponds increased. This issue came to light after the study.

4.4. Market potential of table fish

4.4.1. Market characteristics

A wide range of persons bought fish. Most (89%) had come to purchase fish for household consumption, 11% (*N*=96) had come to market to buy fish for restaurants. Almost all (99%, *N*

= 97) obtained fish from their local market and 57% felt they lived close to the markets. Some of the purchasers had come to do other business rather than specifically to purchase fish.

According to respondents, some species were available markets. The commonest species in all markets were tilapia and Nile perch. Fi hes like *B. docmac* and *L. victorianus* were available in only major markets. Forty-three percent, 60% and 40% of respondents who sometimes consumed *C. gariepinus*, *C. carsonii* and *Protopterus* sp. respectively mentioned that they had purchased it from other, more distant, markets..

Fifty percent of respondents consumed fish 1 – 5 times per month. Fish was most frequently consumed in the East and least in the West. At each vi it most households bought 1 fish while restaurants bought 1 to 4 large fish. The restaurants purchased fish almost daily depending on local availability and customers demand. Fish was consumed more frequently in the BMC Farming System and IBC Farming System.

Table 4.7 Household monthly fish consumption rates by agro-ecological zone

Location	Consumers (*N*)	% of consumers eating fish at each monthly frequency					
		1-5	6-10	11-15	16-20	21-25	26+
BMC	35	20	43	9	14	6	11
IBC	20	35	30	15	5	0	15
WBC	41	73	12	7	5	0	2
Total	96	46	26	9	8	2	8

Note: the information was gathered by interviewing consumers in the fish market, hence all respondents ate fish at least occasionally

4.4.2. Source of fish

The main source of fish to the markets sampled was Lak ictoria. In Ntungamo District fish also came from wholesale fish markets in Mbarara district. In Kampala District, species of fish were from lakes Albert and Kyoga. *C. carsonii* and *C. gariepinus* were also caught from swamps during the rainy season. No pond fish were available from local markets. Both consumers and traders said this was because fish farmers sold all their fish by their ponds.

4.4.3. Supply and demand

Fish supply was most abundant during the rainy seasons and on dark nights when catches were at their peak. As a result of slight seasonal variatio in Busia district fish sellers considered the supply of Nile perch as peaking from July to September and that of tilapia in April and November. *Rastrineobola argentea* ("mukene") supply was considered highest from October to December. Supplies of both tilapia and Nile perch were observed by fish sellers to be at their lowest from December to March. In Bugiri district on the other hand, fish sellers mentioned April as the month when both tilapia and Nile perch were most abundant and November he month when they were least abundant. The supply of Haplochromines *(nkejje)* in Bugiri district was considered lowest during the months of April and August. Supply was also affected by the lunar cycles.

In Ntungamo district, the seasonal supply of C. *carsonii* and *C. gariepinus* in Ntungamo was most obvious. The fish were caught during the rainy season from the local swamps and Lake Nyabihoko. Nile perch and tilapia from Lake Victoria w available throughout the year. In Kampala and Wakiso districts, fish supply was also affected by the state of road networks from the source. During the rainy season, supply sometimes dropped if rains were heavy and roads bad, causing supply to be at its lowest during t e rainy month of September.

The supply of *R. argentea* was considered highest in January. Fish sellers also noted that supply of *R. argentea* and Haplochromines dropped during rainy seasons because they were difficult to sun dry, hence post-harvest losses were higher. The supply of Nile perch d tilapia dropped during the months of July and August because o trong waves on Lake Victoria.

Supply of Nile perch frames from the fish factories an Haplochromines was considered by fish sellers as constant during the year. The quantity of fish into markets also depended on the strictness of fisheries authorities that day.

All fish sellers interviewed considered local fish demand to be high. According to figures from the district records, this translates to an estimated rate of 1.5 kg fish per person per annum in Kampala when its day time population of 3,000,000 is used or 4.5 kg fish per person per annum when resident population figures are sed (estimate 1,000,000). In either case, consumption rates are extremely low given the re ed 12.5 kg fish per person per annum by Balarin (1985). According to fishermen, demand for fish was further associated with seasons, fruitfulness of the harvest and seasonal farm-gate prices of produce. In rural settings where farming was the main occupation, demand peaked d ring the dry season when farmers had no fresh vegetables or fresh beans on their farms. Demand also peaked at the end of harvests especially of cash crops (notably maize and c e). The effect of growing seasons on demand was less pronounced in urban Kampala and peri-urban areas of Wakiso districts. In Kampala demand was influenced by how much money customers had - described by fish sellers as being ‘as long as the fish was in the market and pr es were negotiable’. However, fish sellers in Kampala observed that most fish was bought at the weekends, during public holidays and, in the central wholesale market, on Tuesdays.

Demand in all districts was also affected by the schoo year and festive periods. More fish was bought during the school holidays and festive seasons cept for Christmas and Easter when other meats were preferred. Soon after Christmas and New Year and before the start of the new school year, the cheaper fishes (*R. argentea*, and Nile perch frames) were most marketable as farmers had less cash. Demand for haplochromines was relatively constant but peaked depending on incidences of measles among children (see later)

Consumers also noted that fish was more expensive during the dry seasons because of increased local demand (due to the lack of green veget les) and low supply from the lakes. It was also more expensive during festive periods. Consumers from Ntungamo considered the increase in fish prices during the dry season to be du also to the fact that there was more money in circulation from coffee sales. In Kampala, consumers noted the fish prices were progressively rising because of high demand in the city and probably because fish exports.

4.4.4. Marketability of Fish

The marketability of the different fish was found to b related largely to their inherent characteristics, size and form of processing.

Fish species

The species ranked as most marketable by fish-sellers were tilapia and the Nile perch (Kruskall-Wallis Test, adjusted for ties: P = 0.01). The specie consumed by most consumers sampled (*N* = 97) were tilapia (93%), the Nile Perch (74%), *R. argentea* (34%), *B. docmac* (27%) and *C. gariepinus* (23%). Of the species available on the market, the most favoured among consumers were tilapia and Nile perch (table 4.8 .

Kampala District records for the year 2000 showed that tilapia was the most sold fish. This was largely because of consumer preferences and because most of the Nile perch caught from the lake is exported. Of a total of 4,466 t of fish sold in Kampala district rkets, excluding factory by-products, 56% of sales by weight comprised tilapia, 34% Nile perch and 1% *R. argentea*. The amount of *C. gariepinus* sold through the registered markets was just 8.7 mt.

Table 4.8 Most marketable and preferred fish species

Fish Species	Traders		Consumers Most Preferred Species by Consumer (Respondents = 97)	
	total no.	%	No. of consumers who consume species	No. of consumers for whom species was ranked first choice
Tilapia	57	52	90	67
Nile perch	43	39	72	17
Bagrus sp.	3	3	26	8
Clarias gariepinus	1	1	22	2
Clarias carsonii	4	4	9	0
Labeo sp.	1	1	5	0
R. argentea	4	4	33	0
Protopterus sp.	1	1	8	1
Alestes sp.	1	1	1	0
Mormyrus sp.	1	1	1	0
Haplochromines	2	2		

Information from interviews with fish sellers and cons rs in markets.

Consumers' species preferences were mostly associated with taste, cost and local availability. The reasons for preferred choice were found not to be ignificantly associated with consumers' primary occupation or location.

Tilapia and Nile Perch were ranked high by consumers because they were the most readily available in both major and minor markets. They were also favoured as they were available in various size ranges that were both affordable and pref rred. Tilapia was favoured over Nile perch for its milder taste and smell. *B. docmac, C. gariepinus, L. victorianus, Protopterus* sp. and *Mormyrus* sp. were preferred for their taste, but consumption was limited because of their relatively high costs and low availability. *L. victorianus* and *C. carsonii* were also ranked low because of their fine bones. Nile perch, *Protopterus* and *C. gariepinus* was preferred by consumers with small children because they were fleshy and had fewer bones. It was also mentioned that the preferences of the younger generation were based entirely on what they saw in local markets, because their knowledge of alternative species was limited.

R. argentea ("mukene") and Haplochromines ("nkejje") were purchased because they were cheap and for their nutritive value. The latter was considered by most consumers to be part of the 'treatment' regimen for young children with measle Both species were otherwise ranked low because of their taste, strong smell, bones and th fact that they were often full of stones as a result of poor handling during sun drying. Their small size was not considered a negative factor. These species were bought by the poor.

Product forms

Fish were presented to the consumer as fresh, sun drie , fried, salted or smoked. They were also sold whole, in pieces/chunks or as "frames" (the bones and head of the fish, after the fillets have been removed). There were greater variations in product form in Kampala and Wakiso Districts than in the other districts. Fish sellers c ted whole fresh fish as the most marketable form of fish for all species, except *R. argentea* and the Haplochromines, that were always sold sun dried (table 4.9 and 4.10). However, due to limitations in storage and handling both at source and within the markets, fish of other species o en had to be smoked or fried to improve shelf-life. Thus in areas far from the lake like Ntungamo, more than 80% of the fish sold was not fresh. In both Kampala and Wakiso districts, the emand for fried Nile perch frames was very high in the suburbs or minor markets mostly by youth and as a favourite accompaniment for people having a drink in the evenings[3]. The fresh and smoked forms of Nile perch frames tended to be purchased by families. There was a significant relationship between species a d preference of the fish as fresh, smoked or sun dried by consumers. While most species other than *R. argentea* and Haplochromines were preferred fresh, in the WBC Farming System, more consumers ranked smoked Nile perch higher than fresh Nile Perch. This was due to availability and price.

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[3] In Wakiso district, the fisheries extension worker estimated that 4 mt of Nile erch frames worth USh 2,000,000/= were sold per week in one sub-county, Busukuma which was considered among the poores sub-county's of the district (Walakira, per comm.).

Table 4.9 Proportion of fresh and preserved fish sold in Kampala, 2000.

Species	Total Sales (mt/month)	Proportion Fish Sold Fresh (%)	Proportion Fish Sold Preserved (%)
L. niloticus	1,499	55	45
Tilapia	2,485	83	17
C. gariepinus	8	95	5
TOTAL	4,466	72	28

Adapted from Kampala district fisheries records, 2000. Figures exclude fish factory by-products sold in markets.

Table 4.10 Most Preferred Forms of Fish, as Scored by Fish sellers

Fish Species	Fresh			Smoked			Sun dried			Salted			Fried		
	BMC	**WBC**	**IBC**	**BMC**	**WBC**	**IBC**	**BMC**	**WBC**	**IBC**	**BMC**	**WBC**	**IBC**	**BMC**	**WBC**	**IBC**
Tilapia	128	68	80	74	77	63	35	3	2	3	2	3		4	4
Nile Perch	89	36	56	99	68	59	29		5	4		3		8	4
B. docmac	40		22	34		39	11	4				1		12	2
C. gariepinus	50	9	7	29	12	16									
C. carsonii	30			31		8	2								
L. victorianus	26		4	28			2								
R. argentea	22		3			8	76		48						
P. aethiopicus	42			52											
Alestes sp.						4									

Table reflects most preferred processed form of each fish species in local markets. Total scores were used. Each fish sellers was asked to indicated which was most marketable form of the different specie found in their local market. Data was obtained from the RRAs – markets.

Fish sizes

Consumers and traders were asked in what units they purchased and sold fish respectively. The fish was purchased and sold based on number and size. Sizes were found to be relatively standard in all markets, with fish classified as small, medium or large. Samples of these sizes were measured, and the ranges are indicated in the table below.

Table 4.11 Sizes of Fish Most Frequently Purchased by Consumers

Fish Species	N Respondents	Small fish (0-15 cm) (% N)	Medium fish (15-30 cm) (% N)	Large fish (> 30 cm) (% N)	Parts/pieces (% N)
Tilapia	68	18	21	16	46
Nile Perch	59	3	17	7	42
B. docmac	24	0	42	13	42
C. gariepinus	14	0	21	14	64

Small sized fish: The Kruskal-Wallis test indicated significant differences between species and preferences for small sizes (Kruskal-Wallis Test, adjusted for ties: P-Value = 0.01). The most marketable species as small sizes were the haplochromines, *R. argentea*, *C. gariepinus*, Nile Perch and tilapia in decreasing order. There was also a significant variation between agro-ecological zones and marketability of small sized fish (Kruskal-Wallis Test, adjusted for ties P-Value = 0.00). Between zones, small sized fish were m st marketable in the WBC Farming System.

Medium Sized Fish: There was no significant difference between species d their marketability when they were medium sized, though they were considered of higher marketability in the BMC and IBC Farming Systems than the WBC Farming System. (Kruskal-Wallis Test, adjusted for ties: P-Value = 0.00).

Large Sized Fish: *C. gariepinus*, Tilapia and Nile perch were more marketable when of large size in the BMC Farming System and IBC Farming System than the WBC Farming System (Kruskal-Wallis Test, adjusted for ties: P-Values 0.01 and 0.00 respectively).

Most consumers said their preferred sizes would be medium to large, but because of their higher prices, they often could only afford small fish. Consequently it was those with higher incomes or the restaurants who purchased larger fish. Consumers who run restaurants said they earned more by buying and selling a large fish in piec s than serving whole small fish. Fish such as Nile perch, *B. docmac* and *C. gariepinus* were sold in small pieces/parts, to be affordable. This high demand for small fish has encouraged fishermen not to throw back small (and immature) fish included in the catch, despite legislation forbidding sale of undersize fish.

Competitiveness of fish over other animal products

Consumers ranked fish significantly higher than the ot animal products when asked which of the products they would prefer to purchase when con trained by cash (Kruskal-Wallis Test: P –Value 0.00). The factors that influenced the competitiveness of fish over other animal products among consumers included the following:

Cost: Fish was often the cheapest animal product. In Kampala and Wakiso, and in Busia milk and eggs were considered expensive. The most expensive animal products in all areas were goat and chicken. Although fresh fish is often an expensive form of animal protein, there are cheaper forms such as *R. argentea* and “frames”. Data from Kampala District markets showed that of the animal products (per kg) fish was the third most expensive at UShs. 2,647/- per kg in the year 2002. Chicken cost UShs. 4,196/- per kg, goat UShs. 2,388/- per kg, beef UShs. 2,115/- and milk UShs. 521/- per kg. In 2000, the average fish price per kg was UShs. 1,063/-.

In Bugiri district, the average prices of fish were US 1,600/- per kg, beef UShs. 2,200/- per kg and chicken UShs. 2, 500/- (Fisheries Officer Bugiri district *pers. com.*).

Taste: Of the consumers (N = 65) who cited fish as first choice when short of cash, 20% favoured its taste. Animal products most preferred for their taste were (in order of decreasing preference) beef, fish, milk, goat and eggs (see table 4.12). However, when short of cash consumers would purchase animal products whose taste was preferred by the ntire family rather than some members only. In such cases, eggs (2%, n = 3), pork (5%, n = 6), goat (2%, n = 2) and mutton (2%, n = 2) would not be purchased.

Family size: A number of consumers mentioned that they had large families when listing their reasons for choice of animal product. Hence they preferred products that could be shared out among the family, and fish and milk scored highest.

Culture/Religion: Religion was the most important factor affecting choice, because Moslems and Seventh Day Adventists did not consume pork. Two consumers considered pork a health risk. For cultural reasons some consumers did not consume much goat and mutton. Fish was acceptable to all.

Availability: availability of the product in local markets was also importa (N = 42). Beef, milk and fish were therefore more likely to be purchas than eggs and the other meats. There was a significant association (Chi-square P-Value = 0.00) between the proportion of consumers choosing animal products and local availability. Beef and milk were most readily available and considered cheaper in the WBC Farming System. Fish was most readily available in the BMC

Farming System and IBC Farming System. Eggs were least available in local markets in the WBC and BMC Farming Systems where there is less intensive production.

Nutritive Value: The nutritional value of the animal product was also taken into consideration by 28 of the consumers. Milk, fish and eggs scored highest for this reason.

Satisfaction: The ability to satisfy a family was among the factors cited by consumers, for which milk and eggs scored lower.

Ease of Cooking: Fish, milk and eggs were preferred because they wer easy and quick to cook

.

Another factor affecting purchase of fish was its quality. Consumers mentioned that they would like smoked fish with no sign of deterioration. Sun dr ed *R. argentea* often had many stones.

Table 4.12 Competitiveness of Animal Products

Criteria	No. Respondents	Scores							
		Fish	Beef	Chick en	Eggs	Milk	Pork	Goat	Mutton
Cost	89	105	46	97	65	117	44	78	14
Taste	86	60	72	42	50	60	42	56	42
Family	51	69	18	6	18	30	15	0	0
Religion	24	6	0	0	0	0	68	18	30
Nutrition	28	8	2	0	8	10	0	0	0
Availability	42	15	38	2	2	18	4	4	22

Information from interviews with consumers in markets

Fish prices and units of trade

Most fish sellers (73%) sold fish by size, rather than weight (6%). Some sold fish in pieces (12%), mainly large species such as the Nile perch, *B. docmac*, large tilapia and *C. gariepinus*, to make them affordable. Prices, both at source in markets varied with the season (table 4.13)

Table 4.13 Fish prices for consumers

Fish Species	Small fish (0-15 cm) (Ush.)	Medium sized fish (15-30 cm) (Ush.)	Large sized fish (> 30 cm) (Ush.)	Parts/pieces (Ush/kg)	Amount Consumers Spent at Each Visit (Ush.)
Tilapia	250 –800	500 – 1,400	1,000 – 2,500	1,000 – 1,500	800 – 1,800
Nile Perch	500 – 800	500 – 1,500	800 – 1,800	2,200	800 – 1,500
B. docmac	-	1,300 – 5,500	5,000 – 6,000	1,200 – 5,000	1,200 – 3,000
C. gariepinus	-	1,000 – 1,400	1,200 – 1,500	1,200 – 2,000	1,200 – 1,400
C. carsonii	500	-	-	1,200 – 1,500[a]	-
L. victorianus	-	-	-	2,000 – 2,500	-
R. argentea	-	-	-	500 – 1,000	-
Alestes sp.	-	1,000 – 2,500	-	1,000[b]	-

[a] price per stick; [b] price per piece Data from fish markets

4.4.5. Marketability of pond fish: case study

The case study was used to verify information gathered from other farmers on production and the markets on marketability, i.e. as a form of triang ion. In this case, a female farmer had a pond of 400m^2 stocked with *O. niloticus* and *C. gariepinus* in the ratio 3:1. Feeds used were on-farm residues and occasional maize bran, fish meal and cotton seed cake. The growth period was 8 months. Fertilisation was more regular than feeding and consisted of cow dung and compost laid within a crib in the pond. At harves the farmer sold about half of the fish, consumed some and gave out the rest to friends and relatives.

The farmer found both species to be highly marketable. In the local market (about 1km from the pond) major fish sold are tilapia (mainly smoked, some fresh) and Nile perch (fried and smoked frames, fillet and smoked). Occasionally *C. gariepinus* (only smoked) and *B. docmac* were sold . When available, *B. docmac* was sold by auction at from UShs. 5,000/= to 10,000/= or more per kg .

The farmer sold her tilapia table-sized (300g to 500g) at UShs. 500/= to 1,000/= depending on the size of the fish and negotiating ability of the customer. In the market, the tilapia of the similar sizes (small to medium) sold at UShs. 400/= to 1,000/=. In the dry season prices ranged from UShs. 700/= to 1,600/=. The case study farmer noted that the major advantage she had with respect to tilapia is that it was fresh. Consumers preferred fresh fish, which was not always available except for short periods at certain times of the day. Furthermore, her quality in terms of freshness was higher. To friends and poor farmers around she sold a small fish (about 200g) at about UShs. 300/=.

Local demand for *C. gariepinus* in the area was high whether fresh or smoked. The *C. gariepinus* brought into the market was approximately 30cm long (bout 1kg) and sold for UShs. 2,500/=. The fish seller brought about 100 *C. gariepinus* of this size range to the market once every four days and sold them all, usually within a day. The farmer sold her fresh *C. gariepinus* at about UShs. 2,500/= to 3,000/= per kg on average, the same as the prevailing market price. She sold a 5-kg fish at UShs. 15,000/= and was offered from up to UShs. 8,000/= to 12,000/= for fish weighing 3.5 to 4kg. Her fish were similar sized to those in the market, particularly since the size of *C. gariepinus* brought for sale had dropped over the years. The farmer was able to sell all her fish from the pond side even when she was completely draining her pond for re-stocking, and did not have to take any to the market f ale. All she did was inform her neighbours and friends that she would be harvesting her pond. Listed below (table 4.14) are the range of prices for animal products the rmer gave at the local market.

Table 4.14 Comparison animal products market prices, Kasangati, Wakiso District

Animal Product	Source	Average Price (UShs. / kg)
Tilapia, smoked	market	2,100
Tilapia, fresh	market	2,500
Tilapia, fresh	pond	1,500
C. gariepinus, smoked	market	2,500
C. gariepinus, fresh	pond	2,000
B. docmac, smoked	market	5,000
Nile perch frames, fried	market	500
Beef	market	2,200
Goat meat	market	3,000
Offal (cattle)	market	1,500
Chicken, broiler	market	3,500 each
Chicken, local cock	market	5,500 each
Chicken, local hen	market	4,000 each
Eggs	market	100/= each

4.5. Market potential of *C. gariepinus* as bait

4.5.1. Introduction

As well as being marketed for human consumption, there is a sizeable, but often ignored, demand for some fish species for use as fishing bait. Fishermen and bait traders were interviewed to understand this market. (See appendix L for more details). Among fishermen sampled (N = 184), 64% caught Nile perch as their major fish, 27% tilapia, 19% *C. gariepinus* and 13% *P. aethiopicus*. Forty-three percent of fishermen for whom Nile perch was the major fish (n = 159) caught it with lines. The other species were not del rately targeted in large-scale long line fishing. Tilapia was important among small-scale fishermen who angled from shore. The choice of fishing method among fishermen was determined by the availability of equipment (34%), cost of equipment (8%), catchability 21%), ease of use (33%), availability of bait (2%), ease of maintenance (1%) and whether or a gear could easily be stolen (1%). Ease of use was also related to the level of skill a f sherman had.

The bait used by fishermen for the different species o caught is listed in table 4.15. Of the species used as bait for Nile perch, *Clarias* sp. and the haplochromines/*R. argentea* were most preferred by 42% and 50% of the fishermen (*N* = 67) respectively. The reasons given for preferences were (in order) their availability, preference by the fish, ability to stay alive long (thus attracting fish), and cost.

Table 4.15 Bait used by fishermen, by fish species caught

% fishermen using each type of bait (of those catching each fish species)				
	Species Caught			
Bait	**Nile perch**	**Tilapia**	***C. gariepinus***	***P. aethiopicus***
Haplochromines/*R. argentea*	48	0	28	34
Small tilapia	11	0	15	21
Earth worms	1	76	9	0
Clarias sp.	32	4	19	40
Crabs	1	0	0	0
Nile perch	2	0	0	0
Synodontis sp.	7	0	4	4
Mormyrus sp.	3	0	1	0
Termites	0	6	19	0
Meat	0	0	1	0
Spiders	0	0	1	0
Maggots	0	4	0	0
Maize meal	0	2	0	0
Water insects	0	8	0	0
Labeo sp.	1	0	0	0

The estimated amount of bait a fisherman used per week for Nile perch ranged from 500 to above 4,000 (*N* = 76). Where worms were used, a 0.5 litre tin of worms was used per week. At peak fishing seasons the demand increased to 1,000 -10,000 bait per week. Among the fishermen for whom *P. aethiopicus* was a major catch, the amount of bait required per we ranged from 200–1,000 pieces at peak season. The peak fishing season for Nile perch and the other species was during the rains, from April to August. During the dry months and full moon demand for bait was lower. Small-scale fishermen spent on average UShs. 200/= to 2,700/ on bait for *P. aethiopicus* and tilapia each week.

The major species of bait sold by traders was *Clarias* sp. (77%), *Synodontis* sp. (18%) and Haplochromines/*R. argentea* (5%). Costs varied with the season and size of bait (table 4.16). According to traders, marketable size for bait was from 2" to 4". The price for this size range was UShs. 30-50/= depending on season and availability.

Table 4.16 Unit prices of bait

Species	Cost Price (UShs.)	Retail Price (UShs.)
Clarias sp.	20-150	40-200
Synodontis sp.	20-80	40-100
Haplochromines/R. argentea	50	20-100

4.5.2 Bait trade and supply potential

Among traders interviewed, 14% were usually able to me t demand, 60% never to do so and the rest met demand occasionally. Traders said they would require from 100 to 30,000 *Clarias* sp. per week (see appendix L). A third said their wee demand was above 5,000, but only 12% were able to get this amount. Only traders whose demand was estimated to be less than 5,000 per week were able to obtain their weekly demand. A similar trend was observed in supply of *Synodontis* sp. and Haplochromines. Estimated annual demand for *C. gariepinus* as bait is 4-24 million depending on the scenario (i.e. number of clients, hooks per line).

Table 4.17 Sources of bait for bait traders

Source	***Clarias* sp. (% responses, *n*= 59)**	***Synodontis* sp. (% responses, *n*= 13)**	**Haplochromines (% responses, *n*= 4)**
Kenya	25[a]	69	0
Local swamps and wetlands	47	0	0
L. Victoria/rivers	5	31	100
traders/suppliers	7	0	0

[a] sourced from both swamps and hatcheries.

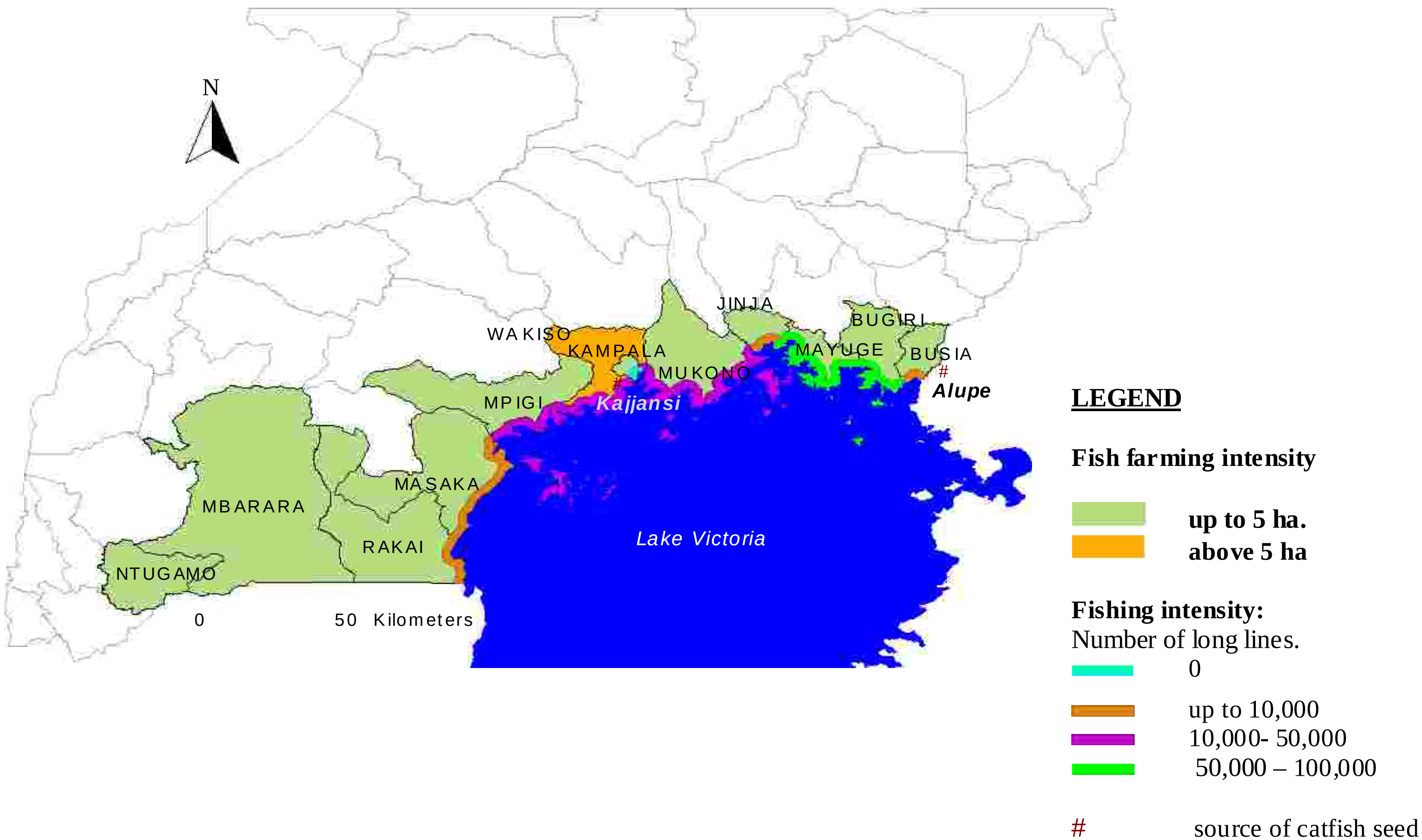

Figure 4.1 Potential Demand for *C. gariepinus* as Seed and Bait.

There were several constraints faced by traders and fishermen in accessing bait. The major constraints were associated with irregularities in supply and distance to source. Bait traders often could not get the desired amount of bait from a single sour particularly off-season. Consequently, they had to travel far, sometimes across borders and spend several days (at times weeks) in order to accumulate sufficient numbers to warrant the effort and cost. Trapping bait in swamps was also time consuming and laborious (table 4.20).

Table 4.18 Constraints faced in the bait trade

Constraints Faced by Traders (n traders = 58)	Score
availability	47
variation in price	7
consistency in supply	10
distance to source	38
legal issues	10
wild animals	19
survival of bait en-route	16
health risks	9
equipment	12
few customers	2
low profit	5
alternatives	5
labour	14
theft of equipment and fish from traps	5
non-payment by fishermen	2

Fishermen also raised issues pertaining to the 'legality' of using bait in long line fishing to catch the prized Nile perch. Traders and fisheries of icers in the districts noted that the size of fish caught as bait of all species were illegal. Use of beach seine nets in Uganda was also illegal. Hence there was a paradox, since long line fishing was encouraged, as it yielded the best quality of Nile perch for the processing plants, was more affordable and helped reduce incidences of 'illegal net sizes'. It also implied that most bait caught using seine nets came from Kenya in the East, yet trade in fish across borde was also supposed to be illegal. Hence traders in bait often got into trouble with the authorities, but had no other alternative.

Most bait was caught at night. This increased the likelihood of attack crocodiles and/or snakes in shallow and swampy waters. Fishermen or tra collecting bait also got bitten by leeches when catching bait in swamps and shallow water Other occupational health risks mentioned included bilharzia and malaria. Furthermore, the stressful conditions under which bait was caught, held for several days and transported resulted in low survival rates en route. Some traders cited lack of access to appropriate facilities for packaging and transporting live fish as a constraint. When the bait was got to the la sites, it was often fatigued. This reduced marketability because fishermen preferred the bait alive and vigorous. Three percent of the bait traders mentioned that the fact that they had no alternative sources as a nstraint.

Table 4.19 Concerns of bait traders if they were to purchase bait from hatchery

Issues	**Proportion of Traders Concerns (% *n* response = 63)**
cost	44
location	68
middle men	2
supply to meet demand	10

Consequently, 83% of the traders said they would appreciate having a single and reliable source of bait. Among fishermen, 70% mentioned they wo purchase *C. gariepinus* bait if it were available from a hatchery. In both cases, the conditions would be that the bait was of good quality in terms of size, fish were alive, prices were fair, location was easily accessible (distances of up to 1km from a landing site or major r ad network were considered accessible) and supply was in concert with fluctuations in demand. Some said they would have to try it out first before they made up their minds. Issues such as redit facilities or being able to purchase some of the bait through bartering with fish were mentioned as factors that would enable them access bait from such a would be supplier. Some of the traders (2%) noted that they would not mind becoming middlemen and would be willing to transp rt the bait from more distant source than mentioned above if supply was guaranteed and large enough.

4.5.3. The perspectives of fisheries officers

Discussions with fisheries extension staff from both in Kenya and Uganda also showed that there was a large deficit in supply for both *C. gariepinus* seed and bait to meet the potential demand of the LVB. The estimated demand for bait in the basin based on the number of registered fishermen with long lines as described in section 3.5.3. ranged from 4 – 24 million per annum. Estimated annual hatchery production of *C. gariepinus* in Uganda was of 930,000 (appendix 4), which production supplied both farmers and lake resto king programmes. District fisheries staff in Bugiri observed that what limited fishermen's use of long lines (for Nile Perch), was the unreliable and low supply of bait. Much of the bait used in the district was from Kenya, which was distant and expensive because of transport costs, particularly for fishermen from the islands. The tightening of controls restricting cross-border sales of fish had made it more difficult for fishermen to obtain bait from across the border. More fishermen had therefore, resorted to the more expensive gill nets. At only one landing site in the district did fishermen predominantly use gill or cast nets.

4.6. Concluding remarks

The socio-economic profiles of fish farmers show that access to land and labour for constructing fish ponds have excluded certain of the poorest households, but that many could own a pond by pooling resources through groups, which has been particularly important for women. The failure of aquaculture to spread widely does not appear to be due to serious constraints on pond establishment. Although farmers d d not believe labour was a limiting factor, this seems to be partly due to their acceptanc of labour shortages as a constant, and their ability to find ways around this. However, this also reflect the fact that they have underestimated the importance of investing time in pon anagement during agricultural seasons, which can have serious consequences for pond profitability (as will be discussed later). Lack of feed and fertiliser for ponds is also widespread, though this may also be a reflection of the low priority which is given to fish ponds compared to competing demands for these resources. As will be discussed, this is also a reflection of the profitability of the ponds under their current management regimes. From the supp y side, then, aquaculture spread has been more limited by constraints in running ponds well (time, inputs) rather than in pond establishment. This would fit well with the observed high number of abandoned and unused fish ponds.

The results from the markets indicate that the local market potential for fish appears good and at the national level, overall supply of fresh fish to consumers is currently stimated to be only about 50% of demand, except in the central region of t e country (NARO/MAAIF, 2000[2]). Consumer preferences for species, for small to medium ized fish for affordability and their preference for fresh whole fish all favour fish farmer . The high marketability for small fish would benefit fish farmers because their capacity to produce fish beyond a certain size is limited biologically and economically. Except in areas very close to markets, fish consumption is limited by the costs (including time) of access to markets: this means that there is a large potential market of currently un-met demand if fish are sold locally by ponds. The prices fish farmers can get also compares favourably with market prices.

Though preferences for tilapia are high, *C. gariepinus* has great market potential as a table fish, since demand is limited by poor local availability. For farmers close to landing sites, there will be greater competition for selling table fish. Here, emand for bait offers another opportunity for fish farming for *C. gariepinus* production. The risks incurred in obtaining bait from the wild make it costly, hence it would be cheaper and easier t ain bait from a hatchery.

CHAPTER 5

Farming systems and their potential for fish farming

5.1. Introduction

This chapter looks at the resources locally available armers for aquaculture as natural and physical assets, which a farmer is likely to draw on as productive capital. The data, much of it qualitative, was generated using the Rapid Rural Appraisal tools described in chapter 3. The availability of assets is discussed with a focus on th farm within the context of agro-ecological zones. Seed and bait as key physical assets for produc ion are also discussed in this chapter.

Most fish-farmers sampled (75%) had mixed farms of crops, livestock and fish, 21% farmed only crops and fish, 3% other enterprises and fish and 1% had crops, others and fish. Whether or not farming units had multiple farm enterprises was significantly associated with a farmer's agro-ecological zone and structure of the fish farming unit (Chi-square P-Values 0.01 and 0.00 respectively). Relatively fewer farmers had multiple enterprises within the IBC Farming System (70%) compared to 96% and 94% of farmers within the BMC and WBC Farming Systems respectively.

Among fish farming units, none of the households had single enterprises while 52% of groups did. (As individuals, members of fish farming groups grew crops and reared other livestock on their personal farms and likewise ranked them first and second respectively.) It was largely fish farming groups located within the IBC Farming System that farmed only fish as a joint enterprise. No significant associations were found indicating an influence of wealth status, age group, farm size or the sex of the head of the farming unit on the kinds of on-farm economic activities.

Among farm enterprises, crops were considered as the most important of the farm enterprises by 75% of farmers. Livestock were ranked second by 55% of respondents and fish third by 64%. Fish were ranked second by farmers who had no livestock. Crops were ranked highest because they met farmers' primary objectives, notably food and income.

5.2 Major farm production characteristics

5.2.1. Crops and crop production practices by fish farmers

The major crops grown by fish farmers in the study are listed below in table 5.1. In the BMC Farming System, maize was the major cash crop. Fish farmers lso grew cassava, rice, some coffee, vegetables and a few fruits as cash crops. In the Western-Banana-

Table 5.1 Crops grown by fish farmers overall and bet een zones

Crops Grown	Number of Farmers (N)	BMC (% of N)	WBC (% of N)	IBC (% of N)	Chi-Square P-Value
banana	61	20	46	34	0.00
cocoa	1	0	0	100	-
vegetables	61	30	36	34	0.19
beans	60	25	42	33	0.07
fruits	58	26	40	35	0.22
sweet potato	54	26	46	28	0.00
maize	41	42	29	29	0.01
coffee	39	15	60	27	0.00
cassava	37	43	24	32	0.01
millet	22	32	68	0	0.57
sugarcane	18	17	33	50	0.00
("irish") potato	9	0	29	0	0.00
sorghum	9	67	33	0	0.00
rice	5	100	0	0	0.00
land fallow	39	26	36	39	0.93
pasture	20	15	50	35	0.20
leguminous trees	6	0	0	100	0.01
trees	26	23	65	12	0.00
groundnuts	13	15	15	69	0.08
soya beans	4	50	25	25	0.51
coco yams	27	15	22	63	0.02
yams	1	0	0	3	-
sisal	3	33	0	67	-
cotton	1	100	0	0	-

Coffee-Cattle Farming System, the main cash crops grown were bananas followed by coffee. In the IBC Farming System, coffee and vegetables were the major c rops. Fish farmers also grew some bananas, cassava and sugarcane for sale.

Bananas and coffee were the principal cash crops within the WBC Farming System and IBC Farming System. The banana was also the major food cr p in these zones. Cereals on the other hand were mostly grown within the BMC Farming System as major commercial and food crops. Most of the commercial vegetable production among fish farmers was done in the WBC Farming System and IBC Farming System. The most important root crops were th sweet potato and cassava, which were grown by relatively more farmers within the WBC and BMC Farming Systems respectively. The scale of production root crops however was highest within the BMC Farming System.

Where bananas, coffee and vegetables were major cash crops farmers fertilised them with animal manures, compost and/or mulched them. Relatively more farmers fertilised their crops within the WBC Farming System (table 5.2). Farmers and extension workers attributed this partly to the effect of small-land sizes and intensified extension services in the d strict two years previous to the study supported by the NGO CARE. Hardly any of the fish farmers fertilised their cereal and root crops. Within the BMC Farming System hardly any farmers fertilised their fields because they regarded their soils as fertile and had comparatively large pieces of land under crop cultivation in relation to livestock numbers. Adequate fertilisation of major crops was therefore impractical, and farmers foc d on fertilising vegetables that were grown in smaller gardens.

Table 5.2 Percentage of fish-farmers by AEZ using fertiliser for crop production

Fertilisation of Major Crops	Number of farmers (*N*)	BMC (% of *n*)	WBC (% of *n*)	IBC (% of *n*)	Chi-Square P-Value
Animal manure, banana	23	9	42	22	0.02
Animal manure banana-coffee mixed	26	0	52	27	0.00
Animal manure coffee	19	4	42	14	0.00
Animal manure, rice	1	4	0	0	-
Animal manure, vegetables	31	17	45	35	0.10
Mulch, banana	19	4	48	8	0.00
Mulch, banana-coffee mixed	11	4	23	8	0.08
Compost, banana	21	4	52	11	0.00
Compost, coffee	17	4	48	3	0.00
Compost, banana-coffee	8	4	16	5	0.20
Compost, vegetables	12	13	26	3	0.02
Artificial fertiliser, vegetables	5	9	3	5	-
Artificial fertiliser, maize	5	22	0	0	0.00
Artificial fertiliser, rice	3	13	0	0	-

N = the total number of farmers from the sample population who used the production techn que.

5.2.2. Livestock production practices

The most commonly reared livestock were cattle, goats nd poultry. Proportionately more of the fish farmers within the WBC Farming System reared livestock than in the other two zones (see table 5.3). They also tended to have more livest

There was no significant variation between the species of livestock reared by fish farmers and agro-ecological zones except that more of the fish farmers in the BMC Farming System and WBC Farming System raised goats than in the Medium Altitude-Intensive-Banana-Coffee Farming System (Chi-Square P-Value = 0.00).

Table 5.3 Influence of Agro-Ecological Zone on numbers of livestock owned.

Livestock Species and Zone	No. of respondents	No. respondents with livestock	Mean herd size (no.)	Minimum (no.)	Maximum (no.)
Cattle					
BMC	23	8	4.3	1	14
WBC	31	15	8.3	1	25
IBC	31	17	5.9	1	30
Overall	85	40	6.5	1	30
Goats					
BMC	23	11	6.4	1	18
WBC	30	20	6.2	2	17
IBC	31	5	5	3	5
Overall	84	36	6.1	1	18
Sheep					
BMC	23	2	4.5	1	8
WBC	30	5	3.8	2	7
IBC	31	3	3	2	3
Overall	84	10	4.3	1	8
Pigs					
BMC	23	2	5	4	6
WBC	30	6	8	1	30
IBC	30	7	4.6	2	12
Overall	84	15	6	1	30
Rabbits					
BMC	23	1	6	6	6
WBC	30	6	12.3	4	30
IBC	30	2	7	4	10
Overall	83	9	10.4	4	30
Chickens					
BMC	23	12	15.7	2	46
WBC	30	18	11.1	1	80
IBC	30	16	130.8	2	540
Overall	83	46	53.9	1	540
Ducks					
BMC	23	0	0.0	0	0
WBC	30	2	1.5	1	2
IBC	31	0	0.0	0	0
Overall	84	2	1.5	1	2
Turkeys					
BMC	23	1	7	7	7
WBC	30	1	6	6	6
IBC	30	0	0	0	0
Overall	84	2	13.5	6	7.0

Information obtained from RRAs

Most fish farmers reared their livestock using extensive management systems (table 5.4).

Table 5.4 Management systems employed by fish farmers for livestock production

Livestock species	Management System (% Farmers)				
	Free-range (%)	Tethered (%)	Paddocks (%)	Intensive (housed/zero grazing) (%)	Both free-range and intensive (%)
Cattle	17.1	36.6	29.3	14.6	2.4
Shoats	11.1	74.1	14.8	0.0	0.0
Poultry	86.0	0.0	0.0	8.0	6.0
Rabbits	0.0	0.0	0.0	100.0	0.0
Pigs	7.7	38.5	0.0	53.8	0.0

Information from RRAs

More intensive methods of livestock production were employed by some farmers within the WBC and IBC Farming Systems. Among the more intensive methods used for ruminants were paddocking in the WBC Farming System and zero-grazing in the IBC Farming System. Piggeries and deep-litter poultry production were done by some farmers within IBC Farming System.

5.2.3. Other activities

Activities undertaken around ponds included pasture, housing, brick making, paddocks, e cultivation, trees, vegetables and sugarcane. In Kampala, housing and brick making were more common; rice and food-crop gardens were common in the BMC Farming System; and trees, vegetables, bees and paddocks in the WBC Farming System. In Wakiso, sugarcane, vegetables and gardens were often found around ponds. In all farming systems, some farmers left bush around their ponds. Most fish ponds were not close to homesteads, but located within the valleys in wetlands, where water was more easily available in the volumes required for pond production. Livestock and crops were kept closest to e. During the day larger livestock depending on the farming system (penned or extensive) were taken down to the wetlands to drink. Otherwise water was ferried to them.

5.3. Potential Inputs for fish farming, source and use

5.3.1. Introduction

Most of the farmers' inputs were obtained locally from within their farms or trading centres.

5.3.2. Feed materials

Farmers used a variety of feedstuffs and feedstuff combinations to feed fish (table 5.5). The most commonly used were pasture/arable crop waste (65), cereal and grain residues (45%) and kitchen/cooking waste (36%).

Table 5.5 Common items used as fish feed among farmers in the different zones

Feed Fed (*N* = 91)	No. of farmers (*n*)	BMC (% of *n*)	WBC (% of *n*)	IBC (% of *n*)	Chi-Square P-Value
Pasture and Arable Waste	58	17.2	43.1	39.7	0.02
Sweet potato *(Ipomea batatus)* leaves	29	20.7	34.5	44.8	0.76
Coco-yam (*Colocasia esculenta)* leaves	36	5.6	50.0	44.4	0.00
Vegetable waste	14	21.4	57.1	21.4	0.12
Kafumbe grass *(Galisoga pariflora and Oxalis latifolia)*	19	10.5	52.6	36.8	0.10
Russian comfrey *(Symphytum peregrinum)*	1	0.0	0.0	100.0	-
Milk leaf	2	100.0	0.0	0.0	-
Cassava	4	50.0	0.0	50.0	0.28
Cassia sp.	1	0.0	100.0	0.0	-
Cereal and Grain Residues	41	41.5	7.3	51.2	0.00
Maize bran	37	35.1	8.1	56.8	0.00
Rice bran	8	87.5	0.0	12.5	0.00
Fish meal	14	14.3	0.0	58.7	0.00
Terrestrial Invertebrates	4	75.0	0.0	25.0	0.06
Oil Seed Cakes	6	0.0	0.0	100.0	0.01
Cotton seed cake	6	0.0	0.0	100.0	0.01
Sunflower seed cake	1	0.0	0.0	100.0	-
Mill sweepings	8	25.0	62.5	12.5	0.15
Kitchen Waste	33	21.2	42.4	36.6	0.44
Rumen content	7	0.0	100.0	0.0	0.00
Brewers waste	5	0.0	20.0	80.0	0.16
Broilers mash	1	0.0	0.0	100.0	-
Lake weeds	1	100.0	0.0	0.0	-

Information derived from RRAs.
N denotes the total number of farmers sampled in the appraisals.
n denotes the number of farmers sampled within the agro-ecological zones.

Pasture/arable crop wastes

The relative use of pasture and arable wastes as feed by farmers was significantly associated with AEZ (figure 5.1). These were more available for aquaculture in the WBC and the IBC Farming Systems. There was no significant association between the use of pasture and arable wastes and wealth status, the structure of the fish farming unit or farm size. The most commonly used arable wastes were coco-yam leaves (40%), sweet potato leaves (32 %), and vegetables (15 %). Within all zones, farmers obtained pasture and arable wastes from their farms. They were, with the exception of sweet potato ves, most abundant during the rainy season. During the rainy season the high demand for sweet potato vines as planting material reduced availability. There was also demand for pasture and arable wastes as animal feed. Peelings and sweet-potato leaves were also fed to tethered cattle, goats nd pigs. Kafumbe grass (*Galisoga pariflora* and *Oxalis latifolia)*, when available, was fed to rabbits. None of the farmers fed their livestock with coco yam leaves. This may explain their greater availability for fish production in the IBC Farming Systems and WBC where they were a common crop within the wetlands. Pasture and arable wastes were obtained free.

Cereal and grain residues

Maize bran (69%) and rice bran (9%) were the most freq ntly fed cereal and grain residues. They were more frequently used to feed fish in the BMC and IBC Farming Systems than the WBC Farming System (figure 5.2). No significant association was found between the relative use of either feedstuff among farmers and their wealth status, farm unit structure, farm size or age group.

Maize bran (98%) and rice bran (91%) were chiefly purchased from nearby trading centres. One of the farmers within the IBC Farming System obtained maize bran from her own mill at no cost.

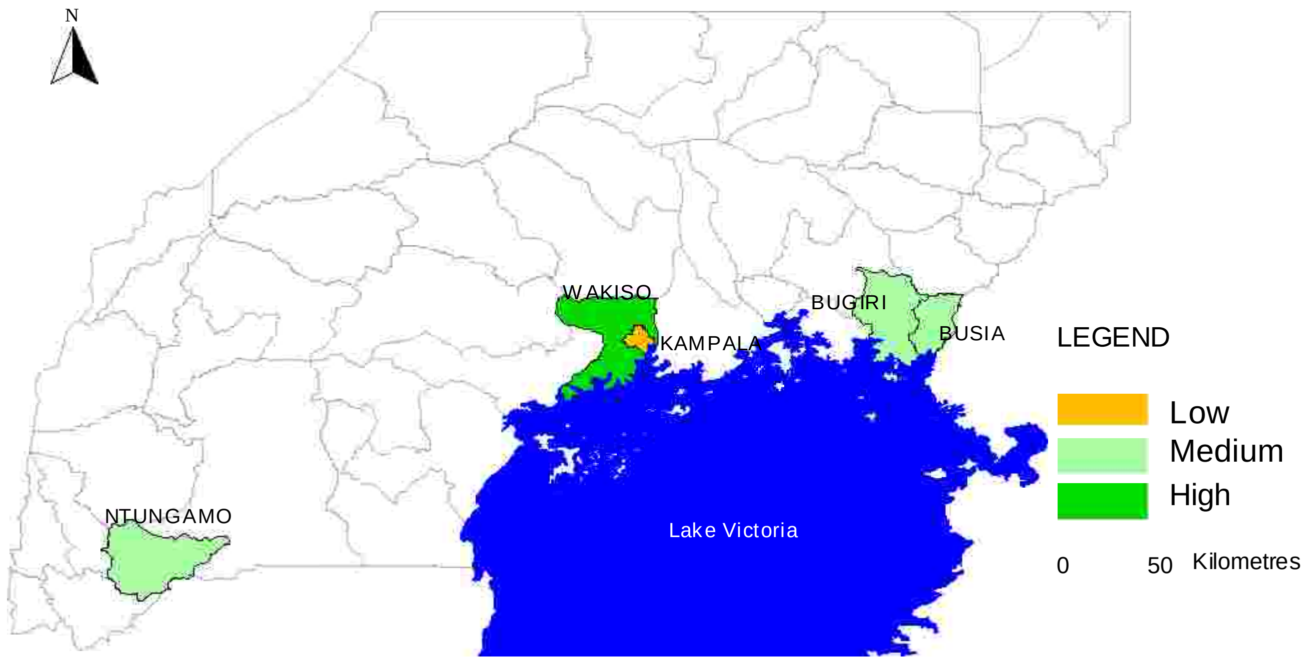

Figure 5.1 Farm pasture and arable waste availability for fish farming in the agro-ecological zones

The availability of maize and rice bran for fish feed depended on the season and disposable cash. Availability was higher at the end of the harvest and was lower, hence more costly, just before and during the growing seasons. Market forces also influenced local pric s and availability. Though maize and rice were grown on a much larger scale as commercial and food crops within the BMC Farming System, trade meant that the price of maize bran was in fact broadly similar in all the zones. Most maize produced in the BMC Farming System was sold whole (unmilled) to major urban centres or export d to Kenya. Bran from locally milled maize was also sold to Kenya for use in animal feed fa ories. Major urban centres were the major destination for cereals and other agricultural produce. Rice on the other hand was hulled within the BMC Farming System where it was grown and sold off as polished rice to other areas. Demand for rice bran as an animal feed ingredient by commercial establishments was also lower, and so it was cheaper and more available locally to farmers within the BMC Farming System than maize bran.

Kitchen waste

There was no significant correlation between use of ki en/cooking waste as a fish feed and the zone. This was also obtained from schools, and in the IBC Farming System was also purchased from eating houses. Availability of kitchen waste was variable. Pigs, dogs and poultry were also fed left over cooked food. Whether or not fish got any would depend on which animals were the priority and what was considered utilisable.

Mill sweepings

Mill sweepings were used more frequently in the WBC Farming System. Their use was statistically not associated with wealth, farm unit structure or farm size. Mill sweepings were more accessible to farmers in the BMC Farming System and WBC Farming System because there were a number of flour mills located locally within small trading centres/villages. In the

IBC Farming System however, most flour was milled in larger establishments some of which also made commercial animal feeds. Small-holder farmers who were able to obtain mill sweepings in the zone did so for deep-litter poultry units. Mill sweepings were from millet, cassava, sorghum and/or maize

Abattoir waste

Abattoir waste was predominantly used as feed in the WBC Farming System where it was obtained free of charge from the local village butcher Within the IBC Farming System the availability of abattoir waste for fish farmers was limited because of competitive demand for commercial livestock feeds. In the IBC Farming System, livestock were slaughtered at established abattoirs and slaughter slabs in and around Kampala, which meant that the waste was not locally accessible in the villages. Where it was available, middlemen, and consequently financial costs, were involved.

Terrestrial invertebrates and aquatic vertebrates

The principal sources of animal protein for fish feed re terrestrial invertebrates (termites) and aquatic vertebrates (fish meal). Termites were largely used as fish feed in the BMC Farming System where they were caught during the rainy season by farmers or by neighbours' children at a cost (table 5.5). Fish meal was more frequently used in the IBC Farming System. The use of fish meal showed no statistical association with wealth status or land size. It was purchased from trading centres and was least available in shops during the rainy season. Use depended on seasonal availability and disposable cash. Fish meal, brans and oil-cakes were fed by preference first to dairy cattle, commercial poultry and pigs.

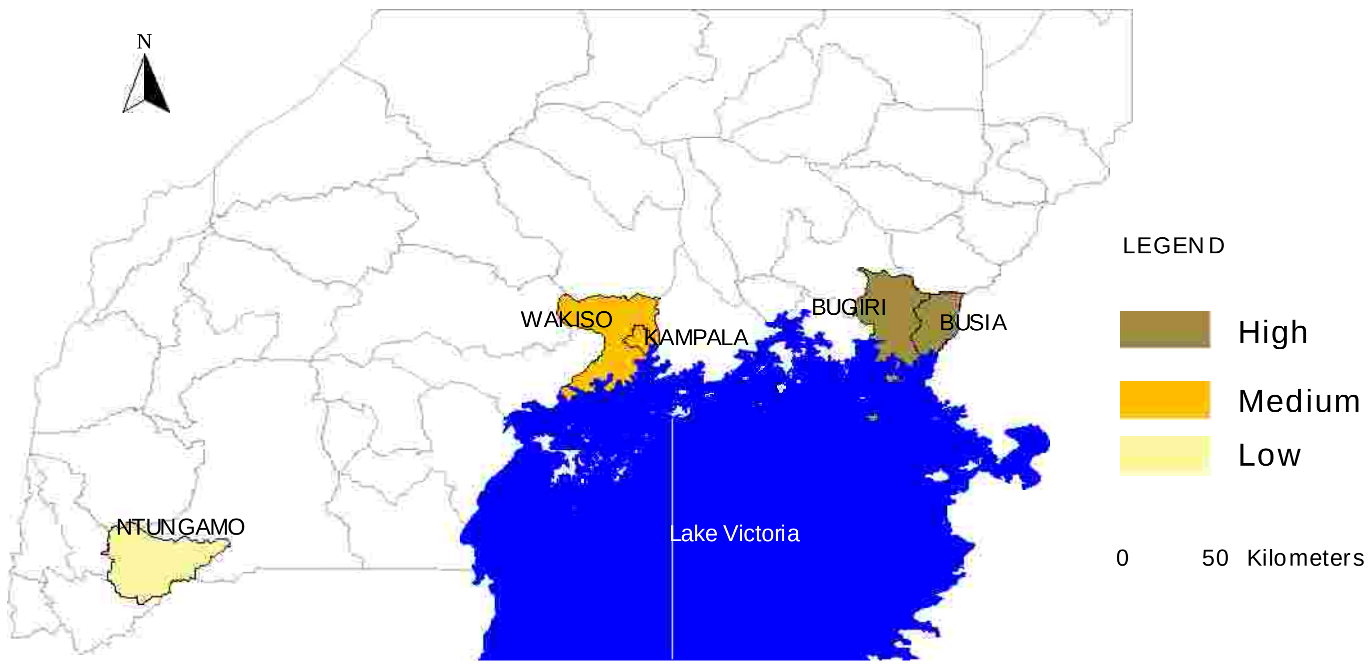

Figure 5.2 Availability of farm cereal and grain residues for fish farming in the agroecological zones

Oil seed residues

Cotton and sunflower seed cake were fed to fish by 6 o e farmers sampled in the IBC Farming System. They were purchased from trading cent es and their use was irregular depending on cash at hand. Though none of these crops were grown within the zone, local availability was influenced by the more intensive animal production practices. Supply was lowest during the rainy season when prices were also at their peak.

Brewers waste

Only five of the farmers sampled fed brewers waste. One was from the WBC Farming System and four from the IBC Farming System. It was obtained from small-scale brewers within local trading centres at a cost. Availability was constant year round.

Table 5.6 Cost of inputs for farmers in each AEZ

Input	Max-Min Cost of Input in Agro-ecological Zones (UShs./kg)		
	BMC	**IBC**	**WBC**
cow dung	0-10	0-20	0.0
goat dung	0.0	0.0	0.0
chicken dung	0-5	0-25	0.0
compost	0.0	0.0	0.0
pig dung	-	0.0	-
maize bran	100-150	50-150	50-200
R.. argentea	250-500	600-700	-
sunflower	-	300-500	-
brewers waste	-	0-20	-
maize flower	-	250-350	300-450
kitchen waste	0.0	0-80	0-45
cabbage	-	-	50.0
rice bran	25.0	25.0	-
blood meal	-	-	0
cotton seed cake	-	150-300	-
yam leaves	0.0	0.0	0.0
banana peels	0.0	0.0	0.0
Kafumbe grass	0.0	0.0	0.0
sweet potato leaves	0.0	0.0	0.0
cassava peel	0.0	0.0	-
pumpkin	-	-	0.0
termites	0-500	-	-

Data from RRAs
'-' indicates that the item was not used by farmers sampled in zone.

Most farmers (61.5%) mentioned that they did not have enough material from their farms to feed their fish. However, this was not considered a constraint by 52% of farmers in the IBC Farming System, mainly for the groups. This was because group members collectively contributed towards feeding in cash or kind (e.g. by bringing leaves and left-overs from their homesteads). More household units in the zone could s mes afford to purchase feed ingredients. Some farmers did not feed their fish eve ere they had possible access to inputs from their farms or from the neighbourhood.

5.3.3. Fertilisers

The commonest fertilisers used by fish farmers were co dung (66%), chicken dung (40%), compost (mostly in cribs) 22% and goat dung 20%. The proportion of farmers using cow and goat dung was significantly associated with agro-ecological zones. Cow dung was most frequently used in the WBC Farming System. Chicken droppings were mostly used in BMC Farming System and IBC Farming System. Fish farming groups in the IBC Farming System used mainly chicken droppings. Goat droppings and compost were most often used by fish farmers in the BMC Farming System (table 5.7).

Table 5.7 Comparative use of fertilisers by fish farmers

Fertilisers Used (N = 91)	No. of farmers (*n*)	BMC (% of *n*)	WBC (% of *n*)	IBC (% of *n*)	Chi-Square P-Value
Cow dung	60	25	47	46	0.00
chicken droppings	36	36	14	50	0.00
Compost	20	40	25	35	0.22
Goat dung	18	67	28	6	0.00
Sheep	1	100	0	0	-
Rabbit droppings	4	25	75	0	-
Pig manure	3	67	0	33	-
Turkey	1	0	100	0	-
Duck	1	100	0	0	-

Information derived from RRAs; ***N*** denotes the total number of farmers sampled in the ap aisals.
n denotes the number of farmers sampled within the agro-ecological zones.

Most farmers obtained fertilisers from their farms. Others got it from neighbours, and occasionally from the local butchers – but not in the IBC Farming System because of the centralised abattoir system in Kampala. In either cas it was obtained at no cost. Manure was sometimes paid for when obtained from sources off-farm

The majority of fish farmers considered the amount of fertilisers they generated from their farms as inadequate for all their farm requirements. his was particularly so in the IBC Farming System. Out of 91 fish farming units sampled, 0% of farmers had other uses for the manure produced apart from fish farming. When the data was disaggregated by structure of fish farming unit, 65% the households and 21% farmi groups had other uses for manure. Where fertilizers were inadequate, 57% of respondents (*N* = 60) mentioned that they would preferably fertilize their gardens while 43% would pre rably fertilize their ponds. Ponds were consequently least fertilised during the planting season when whatever manure was available was used for crop production. The crops that competed for animal manure most were bananas, coffee and vegetables. Farmers who had cess to adequate quantities of compost and mulch as supplements to animal manures for their banana and coffee gardens were more likely to have a bit of manure to spare for their fish ponds. The availability of material to make compost was limited, by the availability of material due to seasonal factors, and the time needed to gather vegetative material.

Animal manure was least available in the BMC Farming System (figure 5.3). The low availability of animal manure in the BMC Farming System was due to the fact that farmers had fewer livestock that were mostly reared by grazing. A few farmers tethered their stock. Furthermore, in the northern part of the district, a lot of livestock were lost due to an outbreak of East Coast Fever complicated with chronic trypanosomiasis in 1999 (Wanyama, *pers comm.*).. Thus availability even among neighbours was low. Despite the low availability, 72% of farmers in the BMC Farming System mentioned that they would prefer to fertilise their ponds before their gardens. This was because they had large gardens, and so they considered it more useful to fertilise a small pond properly rather than stretch what little manure they had inadequately over large fields. Furthermore, the major cash and food crops grown in the zone were not generally fertilised. Where maize and rice were fertilised, artificial fertilisers were sometimes used.

5.3.4. Seed

Overall, a third of farmers considered access to fish seed a constraint, (*N* = 26), 13%, 26% and 41% of farmers in the BMC, WBC and IBC Farming Systems respectively. Farmers (*N* = 83) consequently obtained their seed from several sources namely, the wild (41%), hatcheries (37%) or other farmers (17%). Six percent of fish farming units that constituted groups had received seed through NGOs and did not know the origin source. The fish hatcheries from which farmers obtained seed were Alupe Government Fish Station, Kenya and the Aquaculture Research Centre or SunFish Limited both of which were at Kajjansi, Uganda. All hatcheries sold *O. niloticus*. The hatcheries at Alupe and SunFish farm also produ d *C. gariepinus* seed.

Figure 5.3 Availability of farm manure for fish farming in the agroecological zones

The targeted market for Alupe were fish farmers and fishermen in the Lake Victoria Districts, Kenya, but it was also used by farmers in the BMC Farming System in the east. The hatcheries in Uganda in theory supplied the entire country. Until the change in economic to liberalisation in the 1990s, the Government was supposed to be a supplier of seed for aquaculture. There were several hatcheries around the country until the 1980's. These all collapsed in th civil wars and economic destruction of the 70s and 80s. The private sector is now supposed to meet farmers' demands, but this is a slow process. Only one signif private commercial hatchery is functioning (as of 2004), SunFish Limited, which only began in the last few years. Supply does not meet demand, hence the relatively high proportions of farmers who obtained seed from the wild. In addition, access to seed for farmers was difficult because of the distances to hatcheries. More fish farmers in the WBC Farming System therefore obtained seed from other farmers and the wild than from hatcheries largely beca f the distance to source and the subsequent high costs of transport farmers would have to incur (table 5.8). Seed costs were subsequently affected by demand and supply factors (table 5.9). The total cost of seed for farmers however was much higher. Quantitative data fr m the farmers sub-sampled who incurred their own transport costs (N = 59) indicated that transport costs ranged from 30-300% of the seed purchase cost, depending on the quantities bought and the distance to the seed source.

Table 5.8 Major sources of seed for fish farming in di gro-Ecological Zones

Agro-Ecological Zones (N = 83)	Number of respondents (n)	Source of seed		
		Hatchery (% n)	Other Farmer (% n)	Wild (% n)
BMC	34	50	3	47
IBC	30	40	3	57
WBC	19	26	37	37

Information derived from RRAs.
N denotes the total number of farmers sampled in the appraisals.
n denotes the number of farmers who obtain seed from t is source.

Table 5.9 Comparative seed costs

Source	Unit Cost of Seed (UShs.)	
	O. niloticus	*C. gariepinus*
hatcheries (Uganda)	50	300
hatcheries (Kenya) [a]	40	85
farmer	100-120	-
wild	100-2,000[b]	500

[a] cost based on exchange rate KShs.1 = UShs 21.00 in 1/02
[b] At unit costs above UShs. 1,000/-, seed tended to be adult fish.
Price excludes transport costs

Proximity to reliable sources of C. *gariepinus* has affected its adoption for aquaculture by farmers.

The survival of stocking material was an issue among some farmers. Loss of fish due to unexplained deaths soon after stocking was reported in the WBC Farming System by 13% of the farmers, most of whom had obtained their seed from the wild or other farmers (Chi-Square P-Value = 0.02). In the WBC Farming System, Lake Nyabihoko was an important source of *C. gariepinus* and tilapia (*O. niloticus*) seed. However fish from the lake were reported by extension staff to have lesions during the dry seasons, the period most fish farmers were able to stock their ponds. Only healthy looking fish were selected for stocking. Samples of affected fish obtained during the course of the study were found by the author to be infected with *Diplostomum* sp.

Wild seed was more expensive per unit, but when travel ts to hatcheries were included it was often competitive. In any case, given the unreliab ity of hatchery supply/production, it was often the farmers' only option.

5.4. Water sources and site conditions

Most farmers (97%) had their fish ponds located in wetlands. The major sources of water for ponds were underground sources – springs/wells (59%) and surface water – stream/river/

swamp (38%) or both underground and surface sources (2%). The majority of the farmers considered their water to be of good quality, implying cleanliness at all times. Most farmers were able to get enough water year round to meet their aquaculture needs. However, in the WBC Farming System the prolonged drought experienced in the area in 1999 significantly reduced water supply for aquaculture (Chi-Square P-Value = 0.00). Twenty-three percent (23%) of the farmers' ponds and water sources in this one dried up during that drought.

There were no reported water conflicts regarding access to water with other users except for two cases within Kampala District. Where water sources to ponds were run-off points from communal springs/wells, complaints were made associate h children playing in ponds, or waste water from washing being poured into the pond . Only 3 farmers mentioned r gular flooding as a constraint regarding their sites. All were from the BMC Farming System.

Predators

Sixty percent of fish farmers (*N* = 91) did not consider predators as a constraint to production. However, there was a significant relationship between agro-ecological zones and whether or not predators were a production constraint (Chi-Square P-Value = 0.00). Most of the farmers who cited predators as a constraint were from the BMC Farming System (46%) and IBC Farming System (43%). The prevalence of specific pred rs also varied with location. Monitor lizards were the commonest predator for 52% of fish farmers sampled in the BMC Farming System (Chi-Square P-Value = 0.00). Monitor lizards were not cited in the other two zones. Birds on the other hand were a problem for 48% of farmers in the WBC and 13% of farmers in the BMC Farming System (Chi-Square P-Value = 0.00). Otters were cited by 3 farmers. all from the WBC Farming System. Snakes were mentioned as a constraint by 8 farmers who were distributed in all zones. Some farmers planted plants such as tobacco to keep off snakes.

5.5. Concluding Remarks

The results show that local supply and availability of feed and fertiliser for fish farming was influenced not just by a farmer's location in terms of the agro-ecological zone but also by proximity to urban areas, climatic seasons, farming pr ctices, market factors affecting trade of potential inputs or their by-products and availability of disposable cash to the farmer and market factors. Most physical inputs were required as production inputs in farmers' other farm enterprises. Re-allocation of these resources depended on farmers' ove l livelihood objectives and their perception of the relative return on the inputs from the different enterprises. Because most rural households in Uganda obtained food from their own farms, when biophysical and socio-economic inputs were scarce, scarce resources were all cated to crop and livestock production (Bahiigwa, 1999; MFPED, 2002). Consequently, even where farmers obtained these inputs free from their farms or the neighbourhood, they had significant opportunity costs.

The natural resource assets can be considered as gener lly being adequate. The major natural resource that affects production is water, especially in densely populated areas. The Lake Victoria basin has an estimated total wetland area of 7,448 km^2 of which about 12% has been converted for mainly agriculture and human settlement. Wetland degradation is increasing as demand for land for agriculture, industry and housing reases. Most wetlands are open access resources, except where there is commercial value. In Kampala because of the unclear ownership and high population density, poorer sections of society move into such areas. Mos of the fish farmers also depended on underground water as a water source for aquaculture. Uganda lies on the basement complex of the pre-Cambrian rocks. Underground sources of water are generally considered poor and occur in limited areas along fissure , cracks and joints of the granite-gneiss formation at yields of 0.4-2.0 m^3 per hour (NEMA, 2001). Day time ambient temperatures in the west were also prone to dr own to 15^{o}C during the cold months which may place limitations on production of *C. gariepinus* (NEMA, 2001).

The importance of fish farming in the total resource f on farm was for most farmers small or insignificant depending on the agro-ecological zone in which they were located. This was not quantified in the study because of time constraints and because it was not central to the objective of the study.

CHAPTER 6

Fish farming production systems – current features

6.1. Introduction

Chapter 6 assesses and discusses how fish farmers combined their assets as capital to produce fish. It also identifies and examines the effect of input-output inter-relationships on current production. Consequently the opportunities and vulnerabilities in the system are identified, and from this, the production systems for *C. gariepinus* that may have the potential to improve yields and returns in the current system. The results in this chapter were derived from the quantitative sampling, PCA analysis and partly from the RRAs (*see* chapter 3).

6.2. Pond systems and stocking

6.2.1. Ponds

Farmers' pond sizes varied from 45m^2 to 1,380m^2. The average was approximately 300m^2, though most ponds were approximately 200m^2 (see table 6.1). The average pond depth was 47 cm and most had steep sides. Laboratory results indicated that pond bottom mud from sampled ponds consisted on average of 30% silt. The RRAs showed that the factors that influenced a farmer's decisions on pond size were recommendations by extension staff, land size and availability of labour for construction. Pond depth on the other hand was based on recommendations by extension staff the majority of whom recommended a depth of 50 cm. However, the depth was also eventually influenced by t e pond construction techniques farmers used, i.e. dyke construction and levelling of excavated earth around the po d.

Table 6.1 Pond sizes and depth in the different Agro-Ecological Zones

Location	N respondents	Mean	Minimum	Median	Maximum	Standard Deviation
Pond Sizes (m^2)						
BMC	26	369.2	74.2	209.4	1380.0	324.2
WBC	23	251.6	45.0	209.0	1044.0	234.4
IBC	19	314.1	60.0	250.0	1045.0	245.6
Overall	68	314.0	45.0	215.0	1380.0	275.6
Pond Depth (cm)						
BMC	24	55.28	32.0	50.3	100.0	18.4
WBC	20	46.40	20.0	46.3	75.5	10.9
IBC	19	38.56	20.7	43.0	71.3	12.8
Overall	63	47.42	20.0	46.3	100.0	16.06

Data on pond size and depth was obtained from both RRAs and quantitative sampling, during which actual measurements were taken while having discussions with farmers.

6.2.2. Species farmed

Several species were stocked in ponds. The commonest species farmed were tilapias, African catfish and mirror carp.

Tilapias

Tilapia were farmed by 76% of farmers sampled in the R Significantly more farmers farmed 'tilapia' in the WBC Farming System (94%) and BMC Farming System (83%) than in the IBC Farming System (57%) (Chi-square P-Value 0.00). Proportionately more fish farming households (85%) compared to groups (58%) farmed tilapia (Chi-square P-Value 0.00). The commonest tilapia was *O. niloticus*, farmed by fifty-five percent of farmers. There was no significant influence of zone on the number of farmers farming *O. niloticus, though it was farmed* by proportionately more households (63%) than groups (39%) (Chi-square P-Value 0.03). A farmer's wealth status was also associated with the stocking of *O. niloticus* at the 10% level. At this level of significance, *O. niloticus* tended to be farmed by relatively more of the wealthiest farmers (62%) compared to farmers in the mi dle (32%) and least wealthy (9%) categories (Chi-Square P-Value 0.09). This was because the wealthier farmers could afford to buy seed of the more favoured *O. niloticus* from other farmers, hatcheries or from fishermen, whereas poorer farmers would use whatever fry they cou d find free or very cheaply.

T. zillii was farmed by 9% of fish farming units sampled. Most *T. zillii* farming was done in the IBC Farming System (88%) (Chi-Square P-Value 0.02). There was no significant association between the structure of the farming unit or wealth st and farming of *T. zillii*.

African catfish

The African catfish (*C. gariepinus*) was farmed by 34% of farmers sampled in the RRAs. Most of these farmers (n = 31) were from the BMC (42%) and Medium-Altitude-Intensive-Banana-coffee (42%) Farming Systems (Chi-Square P-Value 0.01). There was no significant association between the structure of the farming unit and wealth status with the farming of *C. gariepinus*.

Mirror carp

The mirror carp (*Cyprinus carpio*) was farmed by 13% of fish farmers, most of whom were from the IBC Farming System. The farming of *C. carpio* showed no significant correlation with wealth status and structure of fish farming unit.

Other species farmed were *B. docmac*, *Cynodontis* sp. and *L. niloticus*. *C. carsonii* was sometimes stocked in ponds by some farmers. These species were also farmed at experimental level by fish farmers.

6.3. Stocking practices

6.3.1. Monoculture vs. polyculture

Sixty percent (60%) of the farmers (N = 91) practiced mono-culture while 40 % practiced mixed culture. Polyculture was practiced more frequently by farme s in the BMC Farming

System (61%) than in the IBC (43%) and the WBC (21%) Farming Systems (Chi-Square P-Value 0.01). The number of species farmed in a pond ranged from 1 to 3, with an average of 1.4. The median and mean number species farmed per pond in the BMC Farming System were 2 and 1.7 respectively compared to a median of 1 and 1 2 in both the WBC and 1 and 1.5 in the IBC Farming Systems. The structure of the fish farm unit had no significant influence on the number of different species farmers stocked per pond.

6.3.2. Stocking ratios

The stocking ratios in *O. niloticus* - *C. gariepinus* and *T. zillii* - *C. gariepinus* polyculture varied among farmers and between zones (see table 6.2). The data on stocking ratios of *T. Zillii*:*O. niloticus* or *T. zillii*:*C. carpio* were verified using both the RRA and quantitative data sets because farmers raising the mentioned species did not have records of the exact numbers of each species that they stocked.

Table 6.2 Stocking ratios used by fish farmers

Polyculture and Zone	*N* farmers	Mean Ratio	Minimum Ratio	Median Ratio	Maximum Ratio	SD
O. niloticus: C. gariepinus[a]						
BMC	11	3.0	0.2	2.9	9.4	2.4
WBC	2	1.4	1.0	1.4	1.7	0.5
IBC	9	8.7	1.5	3.4	27.8	9.2
Overall	22	5.2	0.2	3.1	27.8	6.6
T. zillii & C. gariepinus[a]	2	5.2	1.00	5.2	9.4	5.9
O. niloticus: C. carpio[b]						
BMC	0					
WBC	1	5.0	5.0	5.0	5.0	0.0
IBC	1	0.02	0.02	0.2	0.02	0.0
Overall	2	2.5	0.02	2.5	5.0	3.5
O. niloticus: T. zillii[b]						
BMC	1	1.0	1.0	1.0	1.0	0.0
WBC	0					
IBC	2	1.0	1.0	1.0	1.0	0.0
Overall	3	1.0	1.0	1.0	1.0	0.0

[a] data from farmers sampled in rapid rural appraisals
[b] data from farmers sub-sampled for quantitative data
Ratios are given as the number of fish of the first species listed for each one fish of the econd , e.g. *O. niloticus:C. carpio* of ratio 2.5 means 5 fish of *O. niloticus* to 2 fish of *C Carpio*.

6.3.3. Stocking densities

Table 6.3 shows how stocking densities were affected b different factors. Average stocking densities tended to be higher in the IBC and BMC Farming Systems, among groups and in cases where *O. niloticus* was farmed alone or in combination with *C. gariepinus*. This was attributed to farmers proximity to seed sources, i.e. hatcheries. Farmers with more than 1 pond growing tilapia tended to have lower stocking densities in their extra ponds. This was not necessarily a management decision but due to the fact at a large proportion of farmers with one pond had started production several years earlier when catfish seed was not av ilable, and as was mentioned previously harvesting was not done by most. In more of the newer ponds farmers had adopted newer technology

Table 6.3 The influence of Agro-Ecological Zone, fish farm unit structure, number of ponds a farmer has and species farmed on stocking d ities

Factor	*N* farmers	Mean (fish/m^2)	Minimum (fish/m^2)	Median (fish/m^2)	Maximum (fish/m^2)	Standard Deviation (fish/m^2)
Agroecological Zone[a]						
BMC	20	1.4	0.3	1.4	2.5	0.7
WBC	28	0.8	0.0	0.5	2.6	0.8
IBC	32	2.1	0.2	1.6	7.9	1.5
Overall	80	1.5	0.0	1.2	7.9	1.2
Fish Farm Unit Structure[a]						
household	55	1.4	0.0	1.0	4.7	1.1
group	25	1.6	0.1	1.4	7.9	1.5
Pond Numbers[a]						
Pond No. 1	63	1.5	0.0	1.3	7.9	1.3
Pond No. 2	12	1.4	0.3	1.4	2.5	0.7
Pond No. 3	4	0.8	0.1	0.6	1.8	0.8
Pond No. 4	1	1.0	1.0	1.0	1.0	0.0
Species Farmed[b]						
O. niloticus & C. gariepinus	24	1.7	0.2	1.8	3.4	0.8
O. niloticus	12	2.4	0.3	1.9	5.4	1.9
T. zillii & C. gariepinus	2	1.1	0.9	1.1	1.2	0.2
T. zillii & O. niloticus	4	1.2	0.3	0.7	2.9	1.2

[a] data from farmers sampled in rapid rural appraisals
[b] data from farmers sampled for quantitative data

6.3.4. Size at stocking

Most farmers (74%) mentioned that they had stocked the r ponds with fingerlings. Seventeen percent had stocked what was described as ‘young fish’, 8% stocked adults and one farmer both fingerlings and adults. Farmers described fingerlings as being approximately 5 – 10 cm long, young fish from 7 – 15 cm long and adults above 15 cm long (all in total length). The majority of farmers who had stocked fingerlings were from the BMC (49%) and IBC Farming Systems (33%) while 18%, were from the WBC Farming System (Chi-Square P-Value 0.00). Seventy-eight percent of farmers from the WBC Farming System mentioned that they had stocked ‘young fish’. ‘Young fish’, as described by fish farm were fish that looked small/young, taken from other farmers, ponds or lakes. During the study, samples of ‘young fish’ from other farmers’ ponds often showed signs of stunting. Such fish when actually measured were found to 7-10 cm in total length. Depending on the source, finge ngs might have been ‘real’ fingerlings or ‘small’ fish. Farmers’ responses indic ted that most were aware that ‘fingerlings’ were the desired stocking material. The size of seed stocked also appeared to have been associated with the species stocked (table 6.4).

Table 6.4 Stocking sizes by species farmed

Species in Pond	No. farmers farming species (*N* = *91*)	% farmers stocking with fingerlings (5-10 cm long)	*% farmers stocking with* Older Stock (> 10 cm long)
O. niloticus - C. gariepinus	27	85.2	14.8
O. niloticus	17	70.6	29.4
T. zillii - C. gariepinus	2	50.0	50.0
T. zillii - O. niloticus	4	25.0	75.0
C. gariepinus	1	0	100
T. zillii - C. carpio	0	0	0
C. carpio	2	100	0

Data from RRA sampling

6.3.5. Time to stocking

Time to stocking varied among farmers. Ponds were more often stocked over a period of months (and in one case even eight years!) rather than fully at the start of the production cycle. It generally took farmers longer in the WBC Farming System to stock their ponds (table 6.5). Several of the farmers also mentioned that they had never fully stocked their ponds because of issues pertaining to access, i.e. inadequate sources, distances to source and costs.

Table 6.5 Time to stocking from completion of pond construction

Category	*N* farmers	Mean (years)	Minimum (years)	Median (years)	Maximum (years)	Standard Deviation (years)
Time to stocking						
BMC	23	0.7	0	0	3.0	0.9
WBC	35	0.9	0	0	8.0	1.7
IBC	37	0.7	0	1.0	3.0	0.7
Overall	95	0.8	0	0	8.0	1.2
Time to stocking						
household	27	0.8	0	0	8.0	1.4
group	28	0.8	0	1.0	3.0	0.7
Time to stocking						
Pond No. 1	61	0.8	0	1.0	3.0	0.9
Pond No. 2	25	0.9	0	0	8.0	0.9
Pond No. 3	7	0.4	0	0	1.0	0.5
Pond No. 4	2	0	0	0	0	0

Data obtained from RRAs and PCA. Information was collected in years, rather than months; hence 0 indicates stocking within a year rather and not no stocking.

6.4. Feeding

6.4.1. Feed input levels

Sixty-nine percent of farmers sampled in the RRAs (N = 91) fed their fish and 31% did not. Thirty-six percent of those who were not feeding their fish a the time of the study (N = 28), used to in the past. No significant association was found between whether or not a farmer fed their fish and their location, wealth status or the st   ure of a fish farming unit. Results in table 6.6. show that the actual input levels of differ nt feedstuffs was influenced by the farmer's location (agro-ecological zone). Total input levels on average for p sture and arable wastes plus cereal and grain residues were highest in the IBC Farming System and BMC Farming System respectively. Overall, ponds in the IBC Farming System received a higher feed input. Input levels were also found to vary during the production cycle depending on local availability, farmer's motivation and labour availability.

Table 6.6. indicates that input levels are extremely high, high enough in some cases to impede production as a result of pollution/increased BOD. However, farmer's inputs as feed are bulky,

notably the leafy materials used which are freshly cut before application. Their rate of degradation is low. In addition farmers tied up these leaves in bundles and attached them to posts in the pond. Any left overs at the end of a day or two were removed and more fresh leaves put into the ponds for fish to consume.

Table 6.6 Feed input levels by category of feedstuff and location

Type of Fertilizer/ Zone	No. of respondents	No. of respondents using input	Mean (kg/ha/yr)	Min. (kg/ha/yr)	Max. (kg/ha/yr)
Pasture and Arable Wastes					
BMC	27	6	7,003	2,778	27,961
IBC	19	7	264,928	142	1,262,000
WBC	23	16	25,832	1,379	105,814
Overall	69	29	79,649	142	1,262,000
Cereal and Grain Residues					
BMC	27	10	607,001	4,812	102,857
IBC	19	11	34,015	2,219	110,000
WBC	23	4	10,374	1,984	19,200
Overall	69	25	40,906	1,984	110,000
Mill Sweepings					
BMC	27	4	313	87	727
IBC	19	2	11,652	6,977	16,327
WBC	23	6	18,750	1,482	59,062
Overall	69	12	11,424	87	59,062
Brewer by-Products					
BMC	27	0	0	0	0
IBC	19	5	818,196	18,868	600,000
WBC	23	4	1,377	179	3,273
Overall	69	9	101,276	179	600,000
Household Waste					
BMC	27	0	0	0	0
IBC	19	5	6,660	20	16,326
WBC	23	7	17,857	3,387	59,062
Overall	69	12	13,034	20	59,062
Abattoir Waste					
BMC	27	0	0	0	0
IBC	19	0	0	0	0
WBC	23	1	5,626	-	5,626
Overall	69	1	5,626	-	5,626
Aquatic vertebrates					
BMC	27	2	17,358	17,241	17,476
IBC	19	6	118,832	142	608,442
WBC	23	0	0	0	0
Overall	69	8	93,464	142	608,442
Oil Seed					
BMC	27	0	0	0	0
IBC	19	3	2,880	2,400	3,840
WBC	23	0	0	0	0
Overall	69	3	2,880	2,400	3,840
Fruit Waste					
BMC	27	0	0	0	0
IBC	19	0	0	0	0
WBC	23	1	179	-	179.1
Overall	69	0	0	-	179.1
Terrestrial Invertebrates					
BMC	27	0	0	0	0
IBC	19	0	0	0	0
WBC	23	1	491	-	491
Overall	69	0	491	-	491

The data in the table above was obtained from the sample of farmers from whom quantitative data was obtained, hence figures might not tally direc ly with the qualitative findings in Chapter 5. The table reflects use among farmers. In evels appear high because they were extrapolated linearly not taking into account application regimes as the data used was estimated aggregate data. Farmers did not keep records.

6.4.2. Mixing of feedstuffs

Most farmers (63%) tended to feed more than two feedstuffs simultaneously or concurrently during the production cycle. The number of feedstuffs fed to fish at any one time depended on availability as determined by farm factors (see section 5.3.2) rather than strategy. The chi-square test of association indicated no significant association between mixed feeding and farmers' location or wealth status. None of the farmers sampled had a fixed feeding strategy because while most commonly used feedstuffs could be obtained from their farms, they were often not able to generate sufficient quantities to su tain both fish and other livestock production.

Table 6.7 shows how input levels of different feedstuf s varied as a proportion of total organic input among farmers farming *O. niloticus* only and *O. niloticus – C. gariepinus*. Factors behind this were discussed in Chapter 5. The proportion of an item in the diet was influenced by local availability on farm. Hence where bulky items such as pasture and arable wastes were most available, organic input levels were high. The data f his table was obtained from the quantitative data-set .

Table 6.7 Feeding and fertilisation practices in zones for different species

Species Farmed and Farmers Location	total organic input kg/m^2/y	Category of Input as Proportion of Total Organic Input				
		pasture and arable wastes (%)	cereal and grain residues (%)	other food group (%)	cow dung (%)	other organic fertilizers (%)
O. niloticus						
BMC	12.0	0.0	67.7	5.0	24.3	2.9
WBC	3.5	49.9	0.0	0.5	44.6	4.9
IBC	11.9	8.5	1.0	6.8	56.5	2.2
O. niloticus - C. gariepinus						
BMC	6.3	24.8	35.7	16.9	14.0	8.5
WBC	5.9	54.7	16.2	1.4	27.0	0.7
IBC	17.2	14.3	6.9	22.8	27.2	3.8

6.4.3. Feeding frequencies

From the quantitative sub-sample, 22% of farmers (N = 69) did not feed at all, 46% fed daily, 10% fed once a week, 9% fed several times a week, 4% fed fortnightly, and 9% irregularly. Feeding frequencies were found to be associated with s veral factors.

Structure of fish farming unit: Relatively more households (23%) did not feed their fish at all compared to groups (15%) (Chi-Square P-Value = 0.01). On the other hand, while more of the groups may have fed their fish, they tended to fed less regularly than the household units that did feed. Forty-six percent and 39% of groups (N = 13) fed weekly and less than once a week respectively compared to 70% and 7% of households (N = 56) .

Wealth status: Though no statistically significant Chi-square P-Value was obtained, frequencies indicated that the poorest and wealthiest farmers probably tended to fed their fish more frequently than farmers in the middle wealth group.

Agro-ecological zone: Significantly more farmers in the WBC and IBC Farming Systems fed their fish weekly compared to those in the BMC Farming System (table 6.8).

Table 6.8 Factors influencing feeding frequencies

Factor	*N*	No feeding	Weekly feeding	Less than once a week	Chi-Square P-Value
Agro-ecological zone					0.02
BMC	27	37.0	44.4	18.5	
IBC	19	21.1	63.2	15.8	
WBC	23	4.4	91.3	4.4	
overall	69	21.7	65.2	13.0	
Structure of Fish Farming Unit					0.01
Household	56	23.2	69.6	7.1	
Group	13	15.4	46.2	38.5	
Wealth Ratings					
wealthiest	32	15.6	78.1	6.3	
middle	12	50.0	41.7	8.3	
poorest	9	22.2	66.7	11.1	

Table links socioeconomic and environmental information to feeding practices (data from RRAs and quantitative data)

Feed type: Feeding frequencies were on the whole found not to be significantly associated with the type of feed fed to fish. However, whether or not a farmer fed cereal and grain residues was found to be significantly associated with feeding frequency (Chi-Square P-Value = 0.00). All the farmers sampled who fed fish cereal and grain s (*N* = 28), fed their fish on a weekly basis. Among the farmers for whom cereal and g ain residues were not a feed input (*N* = 26), 65% fed their fish weekly and the rest did not.

6.4.4. Role of feeding in the system

The comparative importance of feed compared to fertiliser as an input showed significant spatial variation associated with AEZ (Chi-Square P-Value = 0.02). More farmers from the BMC Farming System (41%) fed so irregularly that they considered their feed input levels as having no marked effect on yields compared to 21% and 4% of farmers in the IBC and WBC Farming Systems respectively. Feed input was consider d more important than fertilization by 19%, 13% and 37% of farmers in the BMC, WBC and IBC farming systems respectively. Feeding was secondary to fertilization among more of the farmers in the IBC Farming System (37%) than among farmers from the BMC (7%) and WBC (18%) farming systems respectively.

Feeding was considered as important as fertilization by 33%, 26% and 65% f farmers in the BMC, Medium-Altitude-Intensive-Banana-Coffee and WBC farming systems respectively. Similar results were obtained in the PCA analysis of t e overall and *O. niloticus* production systems (see section 6.7).

6.5. Fertilization

6.5.1. Fertilizer input levels

More farmers (80%) fertilised their ponds than fed their fish. The frequency of pond fertilisation among farmers was not significantly infl enced by their location within agro-ecological zones, wealth status or the structure of the farming unit. Only 20% of the 91 farmers sampled did not fertilise their ponds.

The actual amounts of fertiliser used however, varied depending on the type of fertiliser used and between zones. On average, ponds in the IBC and WBC farming systems received more manure than ponds in the BMC farming system. Higher levels of goat droppings were used to fertilise ponds in the WBC farming system and BMC farming system. Input levels for chicken droppings were much higher in the IBC farming system than in the other farming systems (table 6.9). The levels of fertilizer used by farmers varied during the cycle, depending on local availability at any given time rather than according to any set management plan.

Table 6.9 Fertilizer input levels by agro-ecological zone

Zone	No. of respondents	No. of respondents using input	Mean (kg/ha/yr)	Minimum input level (kg/ha/yr)	Maximum Input Level (kg/ha/yr)
Cow dung					
BMC	27	12	21,532	139	60,000
IBC	19	15	66,683	142	310,651
WBC	23	22	46,967	1,163	355,556
overall	69	49	46,774	139	355,556
Goat droppings					
BMC	27	4	1,766	139	3,429
IBC	19	0	0	0	0
WBC	23	9	1,206	203	5,168
overall	69	13	1,378	139	5,168
Chicken droppings					
BMC	27	11	1,564	139	3,429
IBC	19	6	138,838	349	402,516
WBC	23	6	3,236	537	12,255
overall	69	23	37,811	139	402,516
Compost					
BMC	27	4	3,995	800	11,111
IBC	19	1	480	480	480
WBC	23	0	0	0	0
overall	69	5	3,292	480	11,111
Pig dung					
BMC	27	0	0	0	0
IBC	19	1	8,805	-	8,805
WBC	23	0	0	0	0
overall	69	1	8,805	-	8,805
Rabbit Droppings					
BMC	27	0	0	0	0
IBC	19	0	0	0	0
WBC	23	2	600	400	800
overall	69	2	600	400	800

Information obtained from quantitative data.

6.5.2. Mixing of fertilisers

Due to limitations in local supply, farmers used whatever ty e of manure they could get on farm. Thus a fair proportion of farmers (42% of house and 63% of groups) used more than one type of manure. Farmers used up to 4 different types of manure at a time(on average, 2.3, 1.5 and 1.1 types in the BMC, WBC and IBC farming systems respectively). In the IBC

Farming System more farmers use a single type of manur because more intensive systems of livestock management were practiced in the area.

6.5.3. Fertilisation frequency

The frequency with which farmers fertilized their pond red between agro-ecological zones (Chi-Square P-Value 0.00). Farmers fertilized their ponds more frequently in the WBC Farming System than in the BMC and IBC Farming Systems. Sixty-five percent and 68% of farmers fertilized their ponds at least once every for night in the WBC (N = 23) and Medium-Altitude-Intensive-Banana-Coffee (N = 19) farming system respectively. In the BMC Farming System (N = 27) only 37% of fish farmers fertilized their ponds at least once every fortnight, and 33% fertilized their ponds irregularly.

While fertilizer input levels and frequency varied dur he production cycle, there was less variation in the type of manure farmers used during the production cycle.

6.5.4. Importance of fertilisation in the system

The relative importance of fertilization compared to feeding varied between zones (Chi-Square P-Value 0.00). Twenty-three percent (23%) of the farmers from whom quantitative data was obtained did not fertilize or fertilized their ponds irregular and did not consider it worth it. Seventy-five percent of these farmers were from the BMC Farming System. Thirty-seven percent of farmers (N = 19) in the Medium-Altitude-Intensive-Banana-Coffee Fish Farming System considered fertilization secondary to feeding. In the WBC Farming System on the other hand, 65% of farmers (N=23), regarded fertilization as important as feeding. Fertilization was the primary input for 4%, 16% and 22% of farmers in the BMC Farming System, WBC Farming System and IBC Farming System respectively.

6.6. Production and yield

6.6.1. Production cycles

Table 6.10 shows how production cycles varied depending on agro-ecological zones and species stocked. Irrespective of the duration of their production cycle, this had been the only cycle for all the farmers sampled for quantitative dat . Cycles were longest in the West where seed was less accessible and pasture and arable wastes were the major feed input.

Table 6.10 Factors influencing production cycles

Factor	N	Mean (months)	Minimum (months)	Median (months)	Maximum (months)	Standard Deviation (months)
Agroecological Zone						
BMC	19	14.4	2.0	13.0	36.0	8.8
WBC	4	10.8	8.0	10.8	18.0	4.9
IBCLC-FS	15	11.6	3.5	11.6	20.0	5.2
Overall	38	12.9	2.0	12.0	36.0	7.2
By species						
O. niloticus & C. gariepinus	21	13.2	2.0	12.0	36.0	7.6
O. niloticus	10	11.5	3.5	10.0	24.0	6.5
T. zillii & C. gariepinus	1	13	13	13	13	*
T. zillii & O. niloticus	3	16.7	8.0	18.0	24.0	8.1
C. gariepinus	na					
T. zillii & C. carpio	na					
C. carpio	2	16.5	13.0	16.5	20.0	5.0

Information in table is derived from qualitative RRAs and quantitative pond sampling surveys.

6.6.2. Yield

Out of the total number of farmers interviewed in the RRAs (N = 91) 51% had never sampled or harvested their ponds. Table 6.11 shows how severa factors affected yield. The table links socioeconomic findings, farmers spatial location and stocking practices to yield.

Table 6.11 Factors affecting yield

Factor	N	Mean (kg/ha/yr)	Minimum (kg/ha/yr)	Median (kg/ha/yr)	Maximum (kg/ha/yr)	Standard Deviation (kg/ha/yr)
Agro-ecological Zone						
BMC	13	2650	88	1570	11798	3091
WBC	4	1075	111	2603	2267	1079
IBC	13	3262	121	962	13749	4005
Overall						
Species						
O. niloticus & C. gariepinus	20	2946	104	2506	11798	2986
O. niloticus	7	2705	88	888	13749	4912
T. zillii & C. gariepinus	1	814	814	814	814	*
T. zillii & O. niloticus	2	1241	214	1241	2267	1452
Wealth Group						
Wealthiest	9	1435	104	1521	2603	931
middle	6	4639	214	3010	11798	4764
Least wealthy	7	3365	121	1714	13749	4852
Structure of Farm Unit Characteristics						
Family/Household	22	2454	88	2454	11798	2909
Group	8	3396	121	3396	13749	4511
Number of Ponds						
Pond 1	27	2329	88	2329	11798	2760
Pond 2	3	6090	1521	6090	13749	6674
Farming Experience						
Up to 1 year	14	3514	88	2506	11798	3226
Up to 3 years	10	2645	104	622	13749	4206
Above 3 years	5	788	111	601	1709	696
Size at Stocking						
Fingerlings	24	2099	88	1712	9197	1978
Older than fingerling	6	5130	111	2454	13749	6184

Information in table is derived from socio-economic findings (analysis of qualitative RRAs data) nd quantitative pond sampling.

Of the total ponds sampled ($N = 64$), 68% appeared to have attained critical carrying capacity. Results from the table suggest that farmers practicing African catfish and Nile tilapia polyculture have better yields. Those with more than 1 pond appear to be better farmers because in their newer ponds they some have different manageme t systems, notably catfish and tilapia polyculture which they had copied from other farmers. The farmers who had farmed fish longer, tended to have stocked *O. niloticus* only, which over the years had never been harvested hence were overstocked with fish stunted as a result of reproduction.

6.6.3. Quality of yield

There was significant variation between zones with respect to uniformity of fish size among samples (Chi-Square P-Value = 0.03). Only 6 (13%) out of 46 farmers had uniform sizes, all of whom used polyculture. Several ponds were found to ha e different cohorts and wild fish. The number of different size groups from samples ranged fr 1 to 6, average being 2.3. Estimates of numbers of cohorts in a sample may have been inaccurate, as stunted ish could easily have been mistaken to be of a different cohort. At sampling, 61% of farmers were disappointed with yields because of the size range of the sample. Only 30% of farmers who had harvested or sampled their ponds had sold any fish – which is only 15% of all the fish-farmers sampled.

6.7. Interactions and impacts on yield

6.7.1. Introduction

Results from above and the previous chapters derived fr the RRAs and quantitative sampling showed that a large variety of variables influenced yield . Principle Component analysis was used to identify the most important qualitative and q antitative variable(s) affecting production and in what manner these variable acted or interacted to influence production. For details on description and use of variables see chapter 3.

6.7.2. The effect of state variables on yield

Overall farming system

The factors, which were common to all combinations producing significantly higher yields, were associated with seed, i.e. higher stocking density and choice of sp es (see tables 6.12 –

6.14). In all cases, the tables show that seed had significantly high loadings in the component that causes greatest variation 'PC1'. Feed and fertil ser on the other hand were secondary and own their own appeared not to have significant impacts on production without the interaction of seed. The species stocked and the number stocked matt red most in influencing production.

Table 6.12 Overall farming system: effect of feed category on production.

Variable	PC1	PC2	PC3	PC4	PC5
O. niloticus	0.327		0.236		-0.437
C. gariepinus			0.285	0.340	-0.424
Other tilapias			-0.257		
pasture and arable waste		0.364	-0.282	-0.357	-0.338
cereal and grain residues		-0.383		-0.365	
mill sweepings	0.501				
household waste	0.468				
brewers waste		0.372		-0.389	-0.417
oil seed residues					-0.251
aquatic vertebrates	0.273				
slaughter house waste					
fruit and pulp waste					
terrestrial invertebrates					
cow manure	0.276		-0.176	-0.172	0.200
chicken droppings		0.357	0.510		0.200
goat droppings		-0.345		-0.371	
pig manure		0.300	0.553		0.281
rabbit droppings					
compost		-0.417		-0.405	
yield	0.400	-0.027	0.154	-0.082	-0.027
Eigenvalue	3.08	2.44	1.96	1.74	1.55
Percentage variance (%)	18.1	14.3	11.5	10.2	9.1
Cumulative variance (%)	18.1	32.4	44.0	54.2	63.3

* Only a correlation of >0.20 was considered significant

O. niloticus farming system

In the *O. niloticus* farming system, the PC1 – PC3 accounted for 74.9% of variability. In all components, input levels of seed, feed and fertiliser simultaneously had a significant effect on farmers' yields. High stocking densities in combination with high input levels of pasture and arable wastes, coupled with relatively low input levels of cereal and grain residues, household waste and manure had a significant and positive effect n yield (PC1). However, where stocking densities were low, despite farmers' relatively high input levels of pasture and arable wastes, household waste and/or rabbit droppings, yields were low (PC2). PC3 however was associated with increasing yields, despite including l w stocking densities: it also contained low input levels of brewers waste, goat droppings and ompost, but its positive relation with yield was probably the result of increased input levels of oil seed residues (table 6.13).

Table 6.13 *O. niloticus* farming system: effect of state variables on production

Variable	PC1	PC2	PC3
O. niloticus	0.341	-0.279	-0.296
pasture and arable waste	0.218	0.485	
cereal and grain residues	-0.374		
mill sweepings			
household waste	-0.219	0.463	
brewers waste	0.325		-0.458
oil seed residues			0.281
aquatic vertebrates			
slaughter house waste			
fruit and pulp waste			
terrestrial invertebrates			
cow manure	-0.386		
chicken droppings	-0.427		
goat droppings			-0.611
pig manure			
rabbit droppings		0.557	
compost	-0.336		-0.33
yield	0.237	-0.235	0.205
Eigenvalue	4.31	3.00	2.43
Percentage variance (%)	33.1	23.1	18.7
Cumulative variance (%)	33.1	56.2	74.9

O. niloticus – C. gariepinus farming system

The production trend among farmers who farmed *O. niloticus – C. gariepinus* was negative for three out of four PCs (table 6.15). In this system, the interaction between feed and fertilisers alone played a secondary role and had a positive effect on yiel s accounting for 17.9% of variance (PC2). Levels of seed input were important. In PC1 that a counted for 20.7% variation in this system, negative trends in production were associated with low input levels of *O. niloticus*, mill sweepings, household waste and cow manure; thou nput levels of brewers waste and chicken dropping were relatively high. In PC3, low stocking densities of *O. niloticus* and *C. gariepinus* despite relatively high input levels of feed and variables and goat droppings was insignificantly related to production. In PC4, increasing stocking densities of *C.*

gariepinus with low input levels of fertilisers as the only other significant input was significantly associated with reduced yields.

Table 6.14 *O. niloticus-C. gariepinus* Farming System: Influence of State Variables on Production

Variable	PC1	PC2	PC3	PC4
O. niloticus	-0.290		-0.246	
C. gariepinus			-0.462	0.243
pasture and arable waste		-0.293	0.457	
cereal and grain residues		0.389	0.259	
mill sweepings	-0.497			
household waste	-0.464			
brewers waste	0.217	-0.313	0.388	
oil seed residues		0.211		
aquatic vertebrates				
slaughter house waste				
fruit and pulp waste				
terrestrial invertebrates				
cow manure	-0.263		0.262	
chicken droppings	0.203	-0.272		-0.579
goat droppings		0.434	0.255	
pig manure		-0.222	-0.232	-0.601
rabbit droppings				
compost		0.490		-0.229
yield	-0.370	0.132	-0.010	-0.253
Eigenvalue	3.11	2.68	1.98	1.84
Percentage variance (%)	20.7	17.9	13.2	12.3
Cumulative variance (%)	20.7	38.6	51.8	64.0

6.7.3. Interactions between State, Rate (Management) and Intrinsic Variables on Yield

The previous results have indicated that input levels nd management are strongly influenced by intrinsic factors such as their location. It is therefore important to understand more about the influence of such factors.

Overall Farming System

Thirteen percent of variation in production in the ove l farming system was attributable to farmers' management practices and their intrinsic factors (table 6.16). In this system, relatively high production levels were achieved by farmers who ha cking rates and had stocked smaller seed (fingerlings). While such farmers may have had low feed input levels, they fed more frequently and the role of feed in their system was more important or as important as fertilisation. Such farmers were likely: to come from the BMC or in some cases the IBC farming systems; to have smaller farms and ponds; to be relatively new to fish farming; and to manage their ponds as households (PC1). Poorer farmers on the other hand, for whom fertilisers and feed were the more significant inputs nd farmed fish as groups, were less likely to have significantly positive trends in production (PC2).

Table 6.15: Overall Farming System : Effect of State, Rate and Int insic Variables on Production

Variable	PC1	PC2	PC3	PC4
State Variables				
stocking density	0.295		0.220	
organic input			-0.377	0.206
protein input	-0.189	-0.304		
nitrogen input		0.249	-0.377	0.212
Rate Variables				
farm area	-0.301		0.273	0.324
pond area	-0.380			
pond depth		-0.358		
number of ponds		-0.333	-0.269	
size of seed	-0.298		0.202	
culture period			-0.285	0.345
fertilisation strategy				0.517
fertilisation frequency				0.221
feeding strategy	0.296			
feeding frequency	0.224	0.246		0.335
Intrinsic Variables				
AEZ	-0.213		0.374	
age of farmer		-0.251		
wealth status of farmer		0.284		-0.292
category of pond ownership	-0.213	0.226	-0.294	
experience of fish farmer	-0.301		0.273	
age of ponds	-0.216	-0.286		
yield	0.416	-0.046	0.187	-0.055
Eigenvalue	4.34	4.00	3.29	2.45
Percentage variance (%)	20.7	19.0	15.7	11.7
Cumulative variance (%)	20.7	39.7	55.4	67.1

When critical standing crop was included as a variable to refl t the state of the pond, it accounted for 0.5% of variation the overall trend in production in the overall system. It was the most significant variable in where PC1 accounted for 20.8% of variability (appendix L). Though yields in the overall farming system were all s gnificantly positive in the PC1, the weighting of yield dropped when critical standing crop was included as a variable. This showed that as a single variable, it had a large effect of current production trends within the system. Hence the low weighting of yields in PCs wher culture period was a significant variable interacting positively with other variables.

***O. niloticus* farming system**

In the *O. niloticus* farming system 11% of variance in production was attributable to rate and intrinsic variables (table 6.17). When rate and intrinsic variables were included in the analysis, the major state variables (PC1) influencing production were total organic input and ed input. Rate and intrinsic variables played a primary role, the interactio of which however were associated with insignificant and negative yields. Significant trends in production were associated with the interaction between high stocking ensities, shallower ponds, smaller seed sizes, shorter culture periods, increased fertilisation frequency, feeding as important as fertilisation, lower feeding frequencies and fewer yea experience of fish farmer (PC2). The role of fertilisation in the system was significant in PC3.

When critical standing crop[4] and number of cohorts were included in the analysis, ly one PC was obtained and yield coefficient indicated that production was significantly low. This implied that production trends in the system are currently being limited primarily due to ponds having achieved critical standing crop and the number of cohorts in ponds. Critical standing crop and the number of cohorts in ponds accounted for 67% of variability.

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[4] The critical standing crop is the biomass in the pond at which growth starts reducing as a result of limits on the environment (in this case pond) to provide food In this case, ponds with several cohorts and fish showing signs of stunting were assumed to have attaine ir critical standing crop.

Table 6.16 *O. niloticus* Farming System: Influence of State, Rate and Intrinsic Variables on Production.

Variable	PC1	PC2	PC3
State Variables			
stocking density		0.281	
organic input	0.355		
protein input	0.322		0.242
nitrogen input			-0.356
Rate Variables			
farm area	0.321		0.245
pond area	-0.261		0.202
pond depth		-0.395	
number of ponds	0.326		0.234
size of seed		-0.367	
culture period	0.242	-0.257	
fertilisation strategy			0.428
fertilisation frequency		0.241	
feeding strategy		0.313	
feeding frequency	-0.254	-0.239	
Intrinsic Variables			
AEZ	-0.374		
age of farmer			0.282
wealth status of farmer			-0.456
category of pond ownership			
experience of fish farmer	-0.275	-0.225	0.197
age of ponds	-0.283		0.242
yield	-0.047	0.412	0.087
Eigenvalue	6.93	5.48	4.74
Percentage variance (%)	34.6	27.4	23.7
Cumulative variance (%)	34.6	62.0	85.7

O. niloticus – C. gariepinus farming system

In the *O. niloticus – C. gariepinus* farming system, 34.9% of variability in production was attributable to rate and intrinsic variables (table 6.17). Indications were that where farmers engaged in polyculture, the rate variables had greater influence in determining yields than was the case the overall and *O. niloticus* monoculture system where reproduction hence critical carrying capacity were key determinants. Seed size, pond depth, culture period, fertilisation and feeding (PC1 in table 6.17 below) in combination infl enced production most highlighting the

Table 6.17 *O. niloticus-C. gariepinus* Mixed Farming System: Influence of State, Rate and Intrinsic Variables on Production

Variable	PC1	PC2	PC3
State Variables			
stocking density		-0.343	
organic input			0.421
protein input	0.279		0.226
nitrogen input			0.396
Rate Variables			
farm area	0.315		
pond area		0.316	
pond depth	0.302		0.201
number of ponds	0.283		0.212
size of seed			
stocking ratio*	-0.208		0.362
culture period		-0.335	
fertilisation strategy		-0.354	
fertilisation frequency		-0.208	
feeding strategy		-0.272	
feeding frequency		0.352	
Intrinsic Variables			
AEZ	-0.313		
age of farmer	0.213		0.308
wealth status of farmer	-0.300		
category of pond ownership	-0.313		
experience of fish farmer			
age of ponds	0.253		0.252
yield	0.263	-0.155	-0.220
Eigenvalue	7.79	7.31	3.98
Percentage variance (%)	35.40	33.20	18.10
Cumulative variance (%)	35.40	68.60	86.70

* *O. niloticus : C. gariepinus*

importance of managing input rather than quantity of i ut *per se* in determining yields. Intrinsic variables were also primary and indicated th more of the *O. niloticus – C. gariepinus* production occurred in the BMC Farming System among older farmers who tended to be wealthier with several ponds and managed their ponds as households.

6.8. Concluding Remarks

6.8.1. Overview

Results show how farmers combined their assets to produce fish and the effects of these interactions on yield. While farmers primary inputs were similar, input levels and management practices varied between farms and within the production cycle depending on the local availability of resources. They also varied depending on the farmer's location, wealth status and depending on the structure of the fish farm unit. Similar findings have been observed by Veerina *et al.* (1999), among smallholder farmers in India. However, while smallholder farmers in India were more successful, farmers in the ake Victoria Basin failed to achieve their expected yields and production levels were unpredictable.

The primary inputs that affected production were seed, fertiliser and feed. However, the ability of farmers to access these inputs varied and consequently so did yields. Variation also occurred between farmers, within farms and within the oduction cycle. The opportunities and constraints identified affecting production in the current systems are discussed below.

The variation in stocking practices (stocking size, timing of stocking, densities, ratios and pond size) may hint that farmers have little or no experien th fish farming. While this may be true for some, the principle cause for this variation has been difficulties in accessing seed. Availability of seed in the country has been a major problem for farmers (now being addressed by encouraging the private sector become directly involved). Farmers' yields have directly suffered as a result (KARDC, 2000; Isyagi, 2001).

Total organic input levels were rather high. This was attributed to the bulky materials farmers put into their ponds as feed and fertiliser, as explained above. In addition, data provided by farmers was extrapolated linearly in order to have comparisons on a kg/ha/yr basis, in view of farmers' different size and production cycles. This may have distorted some figures.

Using PCA it was possible to identify the key loopholes in the current production systems and potential points through which *C. gariepinus* can be introduced in a manner that enhances production and productivity within farmers local resource and management constraints.

6.8.2. Seed and Stocking

The results showed that *C. gariepinus* had the potential to improve yields in both the overall farming system and *O. niloticus* production systems. The yields varied depending on th sizes of seed and depending on what input levels and management strategy farmers used. In the case of *C. gariepinus* for example, farmers who stocked either smaller or larger sizes may have had good or bad yields depending on what other input and m ent combinations they used. In the case of *O. niloticus* though, poor yields were likely irrespective of the s ze of seed stocked as long as they were reproducing. Likewise the effect on yield of stocking at higher rates and/or ratios depended not only on the species but feed and fertiliser combinations used.

What species should a farmer farm? What should the sto size be? And what should the stocking rates and ratios be for the available levels feed and fertiliser inputs? The following analysis from a SWOT (strengths, weaknesses, opportuni nd threats) perspective summarises the main findings from the study.

Strengths

1. Currently, other than the mirror carp, all the species farmed are local species that are familiar and acceptable to local communities.

Weaknesses

1. The magnitude of the effect of critical standing crop and several cohorts on production trends in the overall and *O. niloticus* indicate that if production levels in this system are to improve, the priority should be to rol reproduction in ponds. In *O. niloticus* production, controlling reproduction is the most important facto if yields are to improve.
2. Currently stocking rates are highly variable and undefined for farmers. The results indicate the importance of stocking rates particularly in the overall and *O. niloticus* farming systems. They show that if production in these systems is to be improved, farmers current stocking rates should increase in light of the available feed and fertiliser inputs. The sizes of seed stocked are curre y also variable in these systems yet the stocking of smaller sizes of fish (fingerlings) shows greater potential to improve production.
3. In the *O. niloticus – C. gariepinus* farming system, indications were that current production trends can be improved by reducing the ratio *O. niloticus:C. gariepinus*, irrespective of the stocking density as long as feed input levels are appropriate. Low stocking densities of either species in this case also resulted in insignificant yields.

Opportunities

1. Indications are that there is a good local market demand for fish and this includes the species farmers are currently farming or attempting to farm.
2. In some cases, the interaction between small pond size high stocking densities and small sizes of seed resulted in positive trends of pro uction for given management regimes. This implies that a management system that o ses these variables, while reducing the production cycle, would be beneficial to the overall system.

3. Increasing stocking densities of *C. gariepinus* alone in the overall system showed the potential to have a significant effect on yields i overall system even where feed and fertiliser input levels were low.

Threats

1. The major threats likely to affect the sustainability of production in relation to seed are low availability and accessibility of seed for far rs. Issues pertaining to supply of seed have affected production negatively both quantitatively and qualitatively. Consequently high levels of dissatisfaction with yields have arisen among farmers after the given production periods. A continuation in this trend would result in more farmers opting out of fish farming.
2. Lack of seed leads farmers to stock several different types of tilapias whose production potential is known to be low.

6.8.3. Feed and fertiliser

The role of feed and fertiliser in the system affected yield in addition to input levels. Certain input combinations and levels resulted in low yields whereas others demonstrated the potential to improve yields for the given stock. For example, in table 6.14 of the *O. niloticus* system, a combination where pasture and arable waste plus brewer aste were primary inputs combined with low input levels of cereal and grain residues, household waste and fertilisation, the trend in yield was significantly positive. Table 6.17 shows that frequency of feeding or fertilising, or the feeding strategy can be associated positively with yields, even where the total input levels are constant. This would indicate that it may be possible in some cases for farmers to maximise the efficiency of their use of limited inputs and so i ove their yields by adjusting the feeding or fertilisation strategy, where these can not be increased.

Strengths

1. Most of the feeds used are from local sources, except nd Kampala.
2. Fertiliser sources are available locally, and currently most organic fertilisers are free-of-charge (i.e. do not need a cash outlay, even if there is an opportunity cost).

Weaknesses

1. In some cases, though feeding frequencies may have be n high, actual input levels both quantitatively and/or qualitatively were low. The results indicate that feeding regimes need to become congruent with production requirements, with frequency of input matched to actual input levels. This applied in all farming systems.
2. Marked seasonal availability of the most affordable an accessible feed inputs for farmers.
3. High reliance on low quality inputs. Consequently in the overall system for example, reliance on coco-yam leaves, *G. pariflora* and cabbage leaves as primary feed inputs resulted had negative effects on production trends. In addition such items were bulky hence apparent high organic input levels, the quality of which for fish production as feed was poor.
4. Though fertiliser application may have been high in so e cases, quantitative levels of input, were low by virtue of numbers of livestock, their management levels and amount of manure that could be generated from each species.

Opportunities

1. Some ingredients such as oil seed cakes showed potenti o improve yields in the *O. niloticus* system.

2. Use of some combinations of feed inputs resulted in positive effects on production. There may be opportunities for developments of low cost feedstuffs, since some items can still be obtained on-farm and can be processed on-farm to improve utilisation by fish.
3. Most farmers farmed tilapia, whose offspring would pro food for prey in predator-prey culture.
4. Fertilisers showed potential to improve yield if input levels could be increased in all systems.

Threats

1. Local supply in some cases was limited due to local agricultural production systems, e.g. due to competitive demand by other livestock for feed, small numbers of livestock owned, extensive livestock systems where manure was mainly lost, etc.
2. Influence of market forces on local supply of inputs f fish farming might fail to compete if it continues to be unprofitable.
3. The PCA suggests that in *O. niloticus – C. gariepinus* farming system, feed was important to increase production. So, if feed input w mited for some farmers, they were likely to have limited production p ential.
4. Amount of fertiliser (animal manure) generated on most farms was not adequate. Even if general agricultural methods improve, supply is unlikely to be adequate for fish ponds unless their contribution to household income makes it worthwhile.
5. Poor farmers are more likely to have smaller animals a farm using more extensive livestock production methods. Hence the quantity o re they could produce is limited. In systems such as the *O. niloticus* farming system

levels of fertilization were important, so production potential would be limited for them.

6.8.4. Intrinsic factors

Farm area affected access to inputs in as much as it i fluenced supply and competitive demand for inputs. Farmers with more or larger ponds did not necessarily have higher yields depending on whether or not their input levels were adequate. However, the number of ponds in some cases influenced the adoption of *O. niloticus*-C. *gariepinus* polyculture, a relatively new system of fish production in the Lake Victoria Basin. Pond depth influenced production in relation to total organic input and stocking densities.

Intrinsic factors also influenced production. The AEZs arming systems influenced the inputs locally available for aquaculture production. Low input levels of chicken manure were likely to be used, because, though poultry were largely available, they were raised free-range by most farmers (except those around the city in the IBC Farming System). Farmers who relied principally on goat droppings also face the constraint of inadequate supply, as well as the problem of its high water stability, and so will be likely to face lower yields. Other than inputs, location influenced production due to distances to reliable sources of seed.

Wealth as an intrinsic factor influenced production largely in terms of farmers access to physical capital as inputs. The wealth status influenced yield in terms of number of ponds, species farmed and their stocking densities, feed and quality of feed inputs. The wealthier farmers were more likely to have higher stocking densities; to farm fish such as catfish whose seed price was higher; and to have a higher total crude protein or feed input. The poorer farmers on the other hand, depended more on fertilisers and farmed more ‘tilapia’, seed that they could obtain easily and cheaply. *C. gariepinus* tended to be farmed by farmers who were more experienced, had more than one pond, and who were wealthier and better able to take the initial risk of farming it. More catfish were farmed in the BMC and IBC Farming Systems than the WBC Farming System .

The key question for farmers was 'How best should I use the inputs at my disposal to ensure the best possible yields?'. The experiments discussed in the next chapter are an attempt to find some answers to this question. The findings suggest that to farm *O. niloticus* the key entry point would be to control reproduction in ponds; whereas to farm *O. niloticus – C. gariepinus* the key entry point would be to manage key inputs, i.e. feeding and fertilisation strategies and frequencies of application in addition to the stocking ratio. Options with short production cycles (rather than several years), stocking of smaller seed, i.e. fingerlings should also be targeted. Indications are also that high production can be realised from small ponds.

CHAPTER 7

The potential of *C. gariepinus* in current farming systems

7.1. Introduction

7.1.1. Objectives

If *C. gariepinus* farming is to be sustainable it must be of benefit to the system and to farmers. This section tries to identify what potential benefits are likely from farming *C. gariepinus* given the opportunities and constraints identified from chapters 4 to 6. Thus bo h grow-out and bait production options for *C. gariepinus* are assessed in relation to *O. niloticus* production, the most commonly farmed species.

7.1.2. Approaches adopted

The choice of experiments was based on the conclusions of the previous chapters, and related to three primary themes – socio-economic, environmental and bio-technical considerations. *Socio-economic considerations*: The primary socio-economic factor taken into account was the farmer's main objective for aquaculture, which is income. Hence factors that were found to affect the marketability of fish notably species, size and price were assessed. Farmers and consumers both ranked tilapia as their most preferred species for aquaculture. Among fish farmers *C. gariepinus* was ranked second as species of choice despite their appreciation of the fact that it had a higher market value and ability to ttain a larger, more marketable, size within a shorter period of time. In their view, tilapia was more tasty and more popul and so more marketable. They also took into account household preferences. This is why a system where *O. niloticus* was the primary species was considered most appropriate. Consideration was also given to costs and availability of inputs for the majo y of farmers in choosing feed and fertilizer inputs for the experiment.

Environmental considerations: Cow dung and maize bran were the most widely used and available inputs in all zones. Maize bran was opted for as a feed input rather than pasture d arable wastes because it was easier to obtain adequate amounts of maize bran to run experiments on-station as opposed to pasture and arable wastes. This highlights some of the practical limitations of institutional research in relation to small farmers' systems. Consideration was also given to the fact that for most farmers, local availability and accessibility of feed and fertilizer as inputs for far ng fish was limited and varied during the production cycle simultaneously or concurrently. Hence the need to optimise feed and fertilizer inputs in similar fashion during production.

Bio-technical considerations: Production in the overall fish farming system was found to be significantly limited by ponds having attained their critical standing crop. When data from the overall system were analyzed as sub-models based on species farmed, the results showed that critical standing crop was the greatest limiting factor influencing *O. niloticus* production. The high weighting of the number of cohorts in the production unit also revealed that this state of affairs was due to fish reproduction. Stocking rates were found to be the second most important variable affecting production levels and trends in the system. The effect of farmers' management practices in response to their production c nstraints was also taken into account. Results from chapter 6 showed how farmers tried to make the best use of resources at hand and how the dynamic management patterns in turn influenced production trends. The effect of t e role and frequency of feeding and fertilization, rearing period and pond size in the system were taken into account.

7.1.3. Experiments

In view of these considerations, *O. niloticus-C. gariepinus* polyculture rather than *C. gariepinus* monoculture was opted for, with *O. niloticus* as the primary species. Two experiments, one testing stocking densities and the other testing varying levels of feed and fertilizer were therefore conducted.

Experiment 1: The effect of stocking density on the yield and returns of *O. niloticus* fed maize bran in earthen ponds fertilised with cow dung

Experiment 1 on stocking density, was initially to have also been a *O. niloticus*-*C. gariepinus* polyculture experiment, however, because of seed constraints, it was conducted as an *O. niloticus* experiment The experiment comprised of four treatments, I to IV, that tested the effect of stocking density at rates of 1 to 4 *O. niloticus*/m^2 respectively (for details see 3.4.2). Experiment 1 was conducted for 124 days, because of pond l ages.

Experiment 2: The effect of varying cow dung and maize bran input levels on pond yield and returns in *O. niloticus* – *C. gariepinus* polyculture.

In experiment 2, *O. niloticus* and *C. gariepinus* were stocked in ponds at the rate of 3 fish/m^2 and ratio of 3 *O. niloticus* to 1 *C. gariepinus*. The experiment tested the effect on production and returns of substituting fertilisers (cow dung) with feed (maize bran) at decreasing rates. The effect of leakage, predation and inconsistencies in application of inputs as a result of constraints in access during the course of the experiment resulted in inconsistencies in growth trends, missing observations within replicates and outliers. The level to which they occurred required that missing observations had to be estimated and outliers corrected in order that statistical inferences could be made.

Estimates of missing observations and outliers were derived based on recommendations by Pauly *et al.* (1993) and Soderberg (1997). Weights were estimated using weight *vs*. time plots. It was found that production trends from some replicat had a better exponential fit and others a more linear fit. According to Soderberg (1997), the linear trends in the weight-length relationship were probably due to the onset of gonadal evelopment that competed with somatic growth. Lengths were then derived using the linearised version of equation 16.

16. $$W = m \cdot L^{v}$$

Hence,

17. $$\log W = \log v + m \cdot \log L$$

Where: W = weight of fish
L = length of fish
v = intercept with ordinate
m = exponent of the length-weight relationship (see appendix 7)

Production of *C. gariepinus* as Bait

Bait production was considered a potential option for *C. gariepinus* production in view of findings from section 6.7.3 that suggested a positive luence on yield in combinations where the following factors had high loadings; smaller pond izes, higher stocking densities, smaller seed size and shorter production cycles. Market factors were also taken into consideration, notably: accessibility of remote farmers to food markets, competition from lake catches where fish farmers close to landing sites and the potential demand for bait.

7.2. Production

7.2.1. Experiment 1: Effect of stocking density on the yield and economic returns of *O. niloticus* fed maize bran in earthen ponds fertilized with cow dung.

By the end of harvest, due to leakages, treatment III 3 fish/m^2) and treatment IV (4 fish/m^2) had one and two replicates respectively out of an init three . The highest net yield was obtained from treatment IV at 4 fish/m^2 (see figure7.1 below). However, ANOVA indicated that there was no significant effect of treatment or b ock effect on total pond biomass. Fish were observed to be larger in treatment I (1 fish/ m^2).

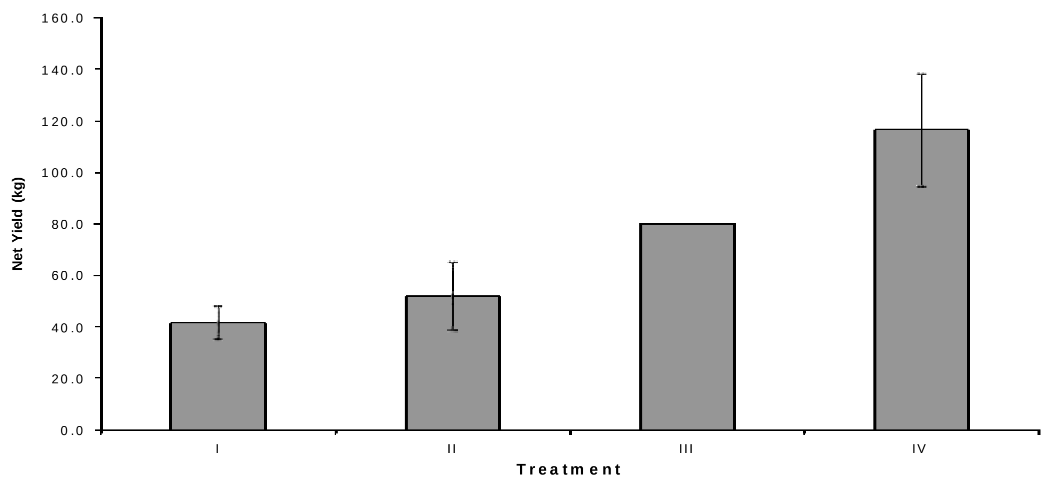


Figure 7.1 ***O. niloticus*** **Monoculture – Net Yields**
Note: There are no standard error bars for Treatment III because by the end of the experiment, two of the replicates had been terminated prematurely due to leaking ponds and predation by birds.

There was a significant effect of treatment on average fish weight. Average fish weights were significantly greater in treatment I compared to treat ents II, III and IV at P<0.04 (figure 7.2 below).

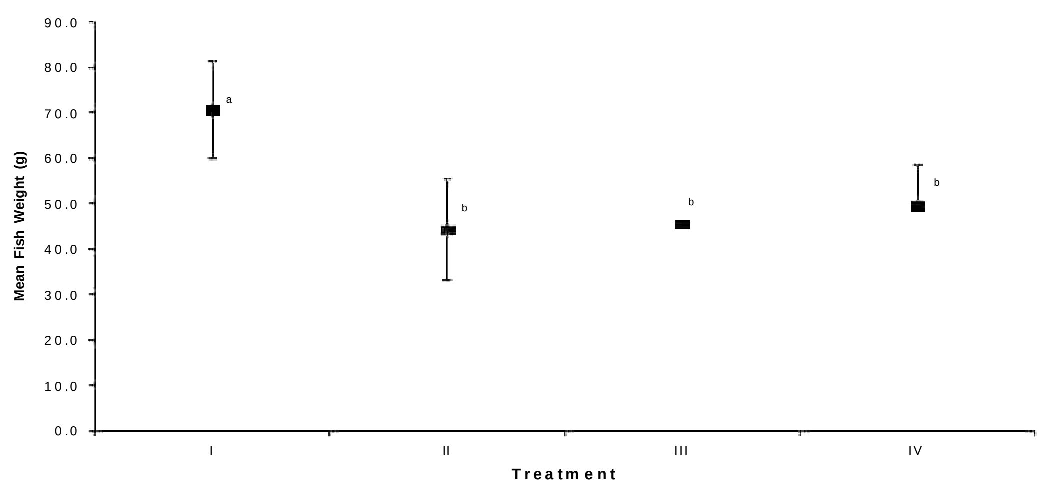


Figure 7.2 ***O. niloticus*** **Monoculture – Mean Fish Weight at Harvest**
Note: There are no standard error bars for Treatment III because by the end of the experiment, two of the replicates had been terminated prematurely due to leaking ponds and predation by birds.
Means with different letters in same figure were significantly different due to treatment effect at P= 0.05.

There was no significant difference in average fish weights as a result of the block effect. There was no effect of between treatment on total length (figure 7.3 below).

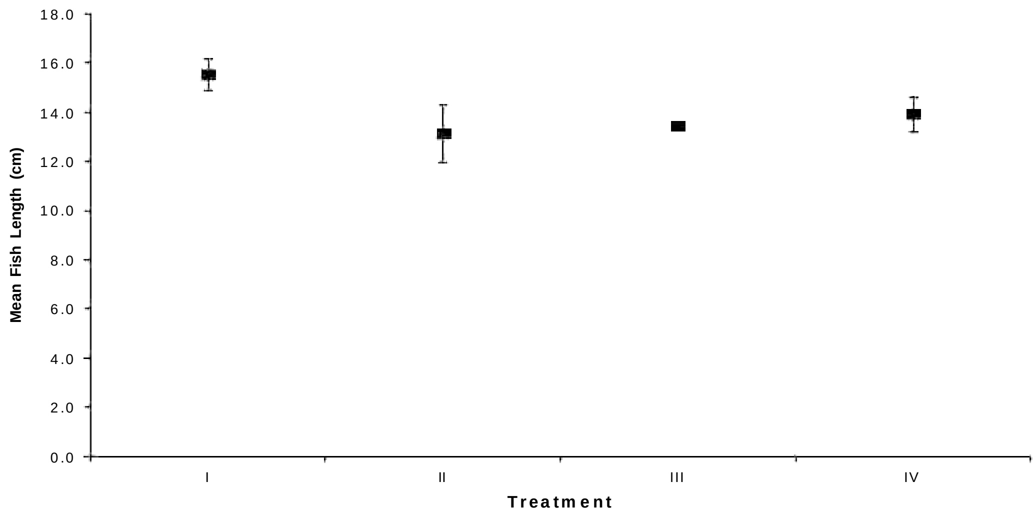


Figure 7.3 *O. niloticus* Monoculture – Mean Fish Length at Harvest
Note: There are no standard error bars for Treatment III because by the end of the experiment, two of the replicates had been terminated prematurely due to leaking ponds and predation by birds.

In terms of efficiency of use of inputs, land and labour were used most productively in treatment IV. While the highest amounts of feed/m^2 were used in treatment IV compared to treatment I, the productivity of feed was constant for all treatments because feed was given as a percentage of total pond biomass (table 7.1 see following page). All treatments received the same amount of fertilizer. The experimental ponds were more productive than farmers' current *O. niloticus* production.

Effect of management factors

FACTOR 1. 44.5% of variability was associated with production, duration in production, feed and manure input and dissolved oxygen levels. Manure input interacted negatively with the other variables. FACTOR 2. 16.8% of variability in production was found to be due to fish stocking density. Feeding and fertilisation also positively influenced the biomass. FACTOR 3. 15.9% of variability was found to be associated with e fects on water quality on fish growth, notably length (see appendix 7).

Table 7.1 Productivity of Experiments, Farmers' Ponds and *C. gariepinus* Bait Production

Experiment	Treatment I	II	III	IV	V	VI	Farmers[b] BMC	WBC	IBC
Experiment 1: *O. niloticus* monoculture									
productivity of land[a] (fish kg/m^2/y)	0.21	0.26	0.40	0.48	-	-	0.14	0.14	0.41
productivity of labour (fish kg/wd)	3.50	4.42	6.83	8.08	-	-	-	-	-
productivity of feed[c] (kg feed /fish kg)	5.01	4.82	5.05	4.93	-	-	25.00	20.00	6.67
productivity of fertiliser (fish kg/ kg fertiliser)	0.06	0.08	0.12	0.15	-	-	0.10	0.02	0.05
Experiment 2: *O. niloticus -C. gariepinus*									
productivity of land[a] (fish kg/m^2/y)	0.21	0.26	0.40	0.48	0.48	0.48	0.32	0.01	0.29
productivity of labour (fish kg/wd)	33.70	43.90	38.30	41.00	56.70	61.90			
productivity of feed[c] (kg feed /fish kg)	*	0.45	2.10	2.70	1.71	2.63	7.69	381.65	50.00
productivity of fertiliser (fish kg/ kg fertiliser)	0.26	0.39	0.39	1.14	**	0.43	0.27	0.01	0.01

C. gariepinus as Bait	***Percent Yield*** 80	70	60	50
Productivity of land (fish kg/m^2/y)[d]	3.93	3.43	2.94	2.46
Productivity of labour (fish kg/wd)[e]	6.54	5.71	4.91	4.10
Feed conversion (feed kg/fish kg)	0.76	0.87	1.02	1.22
Productivity of fertiliser (fish kg/fertiliser kg)	0.36	0.42	0.48	0.58

* Treatment I in experiment 2 had no feed input

** No fertiliser input by farmers in WBC

[a] Productivity of land was based in production per year, in order to allow for comparisons with farmers' current yields.

[b] Farmers' results based on averages by agro-ecological zone.

[c] Farmers' average total feed input included all categor es of feed farmers provided in each case.

[d] Productivity per year, calculated based on 300 days i stead of 365 days in consideration of time required to drain and dry ponds before restocking.

[e] Estimated labour was 42 work days, 1 each production day including time for harvesting.

7.2.2. Experiment 2: Effect of varying cow dung and bran input levels on pond yield and returns in *O. niloticus – C. gariepinus* Polyculture.

Pond biomass increased as the level of feed input increased. Howev r, it was not significantly affected by treatment (P>0.05) (see figure 7.4 below).

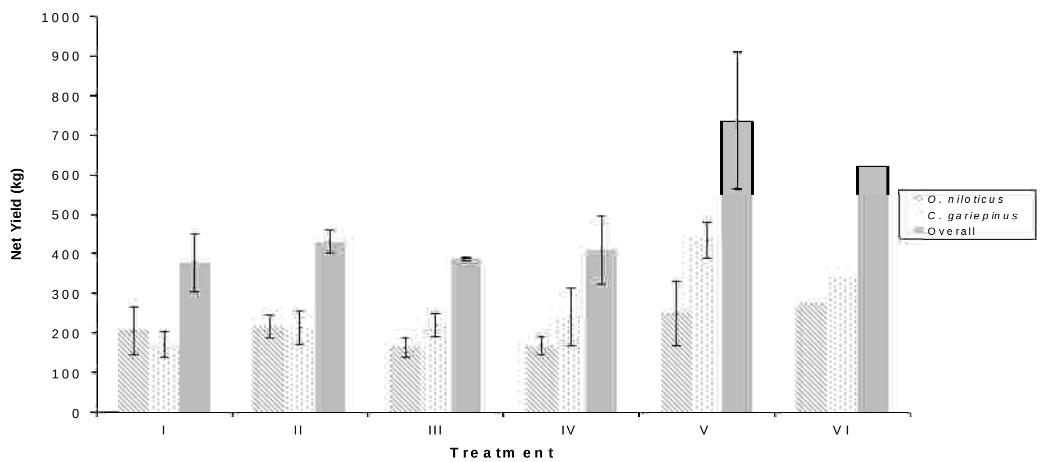


Figure 7.4 *O. niloticus – C. gariepinus* Polyculture – Net Yield
Note: There are no standard error bars for Treatment VI, there were no control replicates for the control. This was because there were no additional ponds on station.

It was noted, though, that in ponds receiving higher i ut levels of cow dung, average weights of *O. niloticus* at harvest were higher. Conversely, average weights of *C. gariepinus* were higher in ponds that had higher input levels of maize bran (figure 7.5 below). There was a significant treatment (P<0.05), species (P<0.05) and interaction of treatment and species (P< 0.05) effect on average weights.

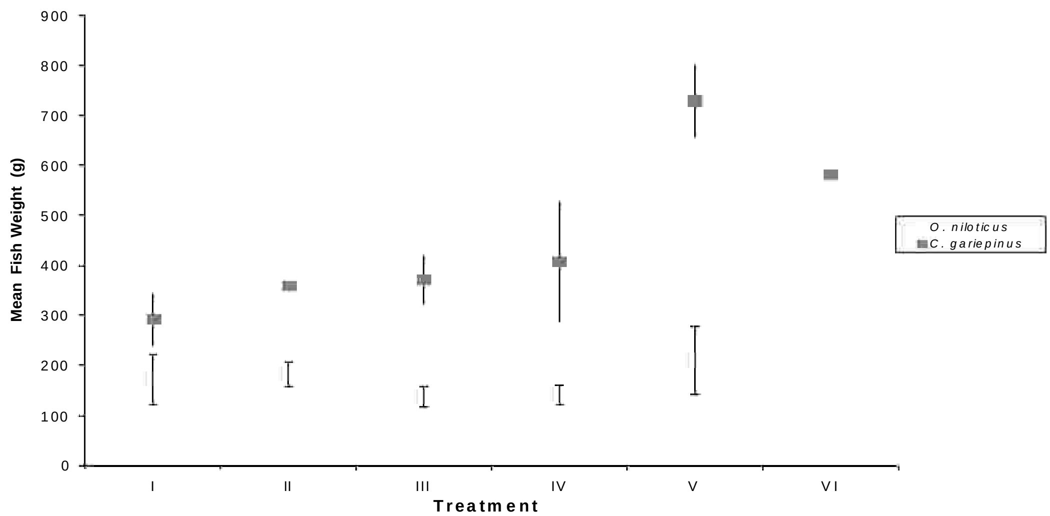


Figure 7.5 *O. niloticus – C. gariepinus* Polyculture – Mean Fish Weight at Harvest
Note: There are no standard error bars for Treatment VI, there were no control replicates for the control. This was because there were no additional ponds on station.

Differences in lengths were due to species differences (P<0.05) rather than treatment effect (P>0.05) (figure 7.6 below).

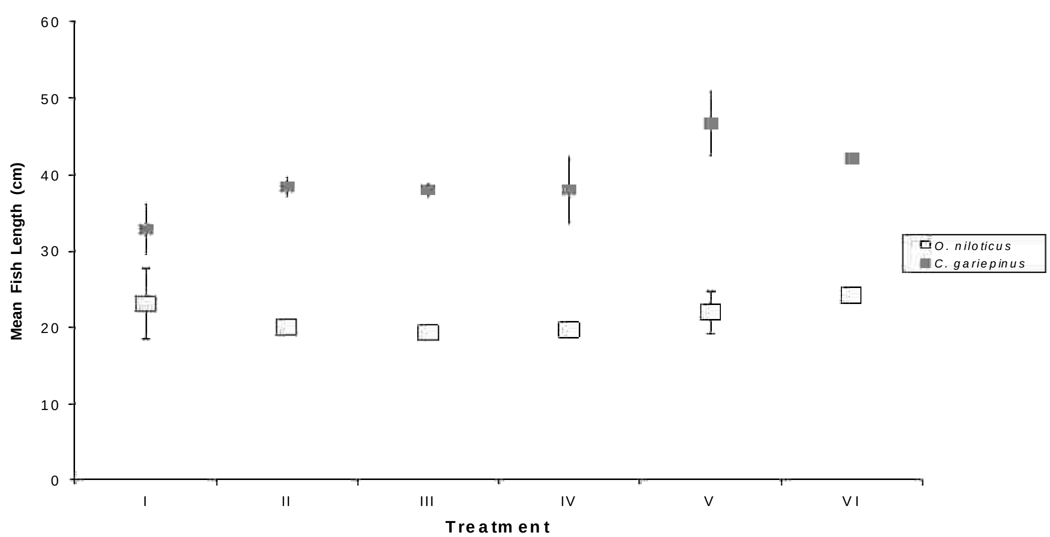


Figure 7.6 *O. niloticus – C. gariepinus* Polyculture – Mean Fish Length at Harvest
Note: There are no standard error bars for Treatment VI, there were no control replicates for the control. This was because there were no additional ponds on station.

Treatments IV-VI were the most productive in terms of yield per unit area. Treatments V and VI utilized labour most efficiently. Most fish was produced per unit of feed input from treatment II. Fertilizer was used most efficiently in treatment IV. Maize bran yielded more fish/kg in treatment II of the monoculture experiment. noculture experiment appeared to have made more efficient use of the feed administer . The polyculture experiment appeared to have resulted in more efficient use of fertilizer. Both experiments were more productive than farmers' current practices in terms of the utilization of feed and fertilizer (see table 7.1). The tables shows that in the *O. niloticus* systems (monoculture), yields of farmers in the BMC Farming System and WBC Farming Systems were 50% less than yields obtained from treatment 1 (1 fish/m^2). In addition the productivity of their feed and fertiliser inputs were up to 80% and 40% less than were obtained from the same t eatment. Farmers' production of *O. niloticus*-*C. gariepinus* was as also less efficient than the experiments in terms of land, feed and fertilizer utilization depending on the treatment.

Effect of management factors

FACTOR 1. 30.25% of variability was associated with f sh production, days in production, feed and total rainfall. All variables had negative coefficients indicating a negative trend in the parameters. This indicated the onset of the rainy season that started mid-experiment, when fish were small and total feed input for all treatments as % body weight was low. FACTOR 2. 12.1% of variability was associated with treatment and fish growth rates. FACTOR 3. 11.3% of variability was attributed to water quality. FACTOR 4. 7.7% of variability was due to the effect of fertilization on water quality parameters, i icating the effect of primary production. FACTOR 5. 5.6% of variability was attributable to pond leakage and its consequent effects on *C. gariepinus* growth and water temperature. It was only with FACTOR 3 that a positive coefficient was associated with production as pond biomass. This was attributed to positive changes in water quality as the effects of fertilisation. The factor was associated with no rainfall and positive input of fertiliser.

7.2.3. *C. gariepinus* bait production

Production was based on 12 nursery ponds each being about 500 m^2. The stocking rate was 160 fish/m^2. The production cycle was 7 weeks to attain fish of mini um 3″ (7.5 cm). Fish were fed a diet of 39% CP. Total feed and manure input over this period were 210 kg and 100 kg respectively. Harvest weight would be approximatel 344 kg fish (average 4.5g/fish) depending on survival rates. Production was highly variable. To a large degree this was because of predators, notably frogs (*Xenopus* sp.), birds and crayfish (*Procambrus clarkii*). Results indicate that bait production was more efficient than *O. niloticus* monoculture in terms of the use land, labour, feed and fertiliser depending on the percent yields. The utilization of fertilizer was found to be more comparable to experiment 2 (see table 7.1). However, the quality of feed used by SunFish Farm Ltd for *C. gariepinus* seed production was 39% CP compared to 13% CP for maize bran.

Productivity of labour: More kilograms of fish were produced per day from po yculture than *O. niloticus* monoculture or bait production. Returns to labour were therefore potentially higher from polyculture and bait production depending on the treatment and level of yield respectively (i.e. also varied with different treatment levels). H ce where labour is a constraint, it would be more worthwhile to engage in polyculture. In experiment 1, the productivity of labour was so low that returns were negative where opportunity costs were included in economic analysis.

7.3. Economic Analysis[5]

7.3.1. Returns

Table 7.2 shows how returns differed between experiments. Whole fish were predominantly sold in markets and by farmers based on number and size. Based on these criteria, when fish were sold by kilogram, returns were lower. Experiment 1 was not profitable when returns were based on fish sales by weight. However, when priced according to size and returns based on number of fish, profits were positive for all treatments, up to 5 times as high as when fish was priced per kilogram (table 7.2a). In experiment 2, production was profitable when yields were priced based both on weight or number or size. Again, profits increased by up to 5 times when fish were priced by number and size rather than by weight (table 7.2b). In the case of bait, there was no change observed when fish were priced based on weight or number and size because estimation of yield in weight was done by cross-multiplication, based on unit average weight of fish at harvest (table 7.3).

[5] Note: Calculating value of harvests depends on optima growing period for each stocking density. In experiments 1 and 2, the study could not go beyond 124 ays and 241 days respectively. (The latter is more likely to be optimal.) Different production cycles may have different optimal king densities. This in turn will affect profit sensitivity to price of seed (which is proportional to the stocking density).

Table 7.2a Economic returns based on station costs for experiment I

Inputs	Experiment 1			
	I	II	II	IV
O. niloticus (no.)	600	1200	1800	2400
C. gariepinus (no.)	0	0	0	0
Feed (kg)	361	448	636	880
Fertiliser (kg)	660	660	660	660
Estimated Labour (wd)	12	12	12	12
Value of Inputs				
O. niloticus (UShs)	30,000	60,000	90,000	120,000
C. gariepinus (UShs)	0	0	0	0
Feed (UShs)	36,100	44,800	63,600	88,000
Fertilizer (UShs)	0	0	0	0
Labour (UShs)	0	0	0	0
Total Variable Cost	**66,100**	**104,800**	**153,600**	**208,000**
Net Yield				
O. niloticus (kg)	42	53	82	97
C. gariepinus (kg)				
Pond Yield (kg)	**42**	**53**	**82**	**97**
Net Total Yield (kg/yr)	**124**	**156**	**241**	**286**
ECONOMIC RETURNS (by weight)				
Value of Yield				
O. niloticus	50,400	63,600	98,400	116,400
C. gariepinus				
Gross Income	**50,400**	**63,600**	**98,400**	**116,400**
Profit, excluding labour costs (UShs.)	-15,700	-41,200	-55,200	-91,600
Returns to investment, farmers view	-52%	-69%	-61%	-76%
Returns to investment, economists view	-24%	-39%	-36%	-44%
Returns to labour (UShs.)	-1,308	-3,433	-4,600	-7,633
Returns to land (UShs.)	-26	-69	-92	-153
Break-even price (UShs./kg)	535	672	636	728
Break-even production (kg)	55	87	128	173
Ratio of profit to operating cost	-0.2	-0.4	-0.4	-0.4
ECONOMIC RETURNS (numbers)[a]				
Value of Yield				
O. niloticus	144,000	288,000	432,000	576,000
C. gariepinus	0	0	0	0
Gross Income	**144,000**	**288,000**	**432,000**	**576,000**
Profit, excluding labour costs (UShs.)	77,900	183,200	278,400	368,000
Returns to investment, "farmer's view"	260%	305%	309%	307%
Returns to investment, "economists view"	118%	175%	181%	177%
Returns to labour (UShs./work-day)	6,492	15,267	23,200	30,667
Returns to land (UShs./m^2)	130	305	464	613
Break-even price (UShs./kg)	138	109	107	108
Break-even production (kg)	220	349	512	693
Ratio of profit to operating cost	1.2	1.7	1.8	1.8
ratio receipts numbers/weight	-5.0	-4.4	-5.0	-4.0

[a] Value of Yield based on actual average size at harvest and numbers at 80% yield. In Experiment 1 *O. niloticus* valued at UShs 300/-. In Experiment 2, *O. niloticus* valued at UShs. 600/- and *C. gariepinus* UShs. 1,800/-.

Table 7.2b Economic returns based on station costs for experiment II

Inputs	Experiment 2					
	I	II	II	IV	V	VI
O. niloticus (no.)	1200	1200	1200	1200	1200	1200
C. gariepinus (no.)	600	600	600	600	600	600
Feed (kg)	0	200	815	1122	978	1641
Fertiliser (kg)	1440	1125	990	360	0	1440
Estimated Labour (wd)	40	40	40	40	40	40
Value of Inputs						
O. niloticus (UShs)	60,000	60,000	60,000	60,000	60,000	60,000
C. gariepinus (UShs)	180,000	180,000	180,000	180,000	180,000	180,000
Feed (UShs)	0	20,011	81,500	112,195	97,783	164,100
Fertilizer (UShs)	0	0	0	0	0	0
Labour (UShs)	0	0	0	0	0	0
Total Variable Cost	**240,000**	**260,011**	**321,500**	**352195**	**337,783**	**404,100**
Net Yield						
O. niloticus (kg)	207	219	165	170	185	274
C. gariepinus (kg)	175	215	223	245	387	349
Pond Yield (kg)	**382**	**434**	**388**	**415**	**572**	**623**
Net Total Yield (kg/yr)	**580**	**658**	**587**	**629**	**865**	**944**
ECONOMIC RETURNS (by weight)						
Value of Yield						
O. niloticus	248,832	263,184	198,012	204,156	221,628	328,524
C. gariepinus	262,950	323,145	333,960	367,290	580,035	419,088
Gross Income	**511,782**	**586,329**	**531,972**	**571,446**	**801,663**	**747,612**
Profit, excluding labour costs (UShs.)	271,782	326,318	210,472	219,251	463,880	343,512
Returns to investment, farmers view	453%	544%	351%	365%	773%	573%
Returns to investment, economists view	113%	126%	65%	62%	137%	85%
Returns to labour (UShs.)	6,795	8,158	5,262	5,481	11,597	8,588
Returns to land (UShs.)	453	544	351	365	773	573
Break-even price (UShs./kg)	414	395	548	560	390	428
Break-even production (kg)	200	217	268	293	281	337
Ratio of profit to operating cost	1.1	1.3	0.7	0.6	1.4	0.9
ECONOMIC RETURNS (numbers)[a]						
Value of Yield						
O. niloticus	576,000	576,000	576,000	576,000	576,000	576,000
C. gariepinus	864,000	864,000	864,000	864,000	864,000	864,000
Gross Income	1,440,000	1,440,000	1,440,000	1,440,000	1,440,000	1,440,000
Profit, excluding labour costs (UShs.)	1,200,000	1,179,989	1,118,500	1,087,805	1,102,217	1,035,900
Returns to investment, farmer's view	2,000%	1,967%	1,864%	1,813%	1,837%	1,727%
Returns to investment, economist's view	500%	454%	348%	309%	326%	256%
Returns to labour (UShs./ work-day)	30,000	29,500	27,963	27,195	27,555	25,898
Returns to land (UShs./m^2)	2,000	1,967	1,864	1,813	1,837	1,727
Break-even price (UShs./kg)	250	271	335	367	352	421
Break-even production (kg)	800	867	1072	1174	1126	1347
Ratio of profit to operating cost	5.0	4.5	3.5	3.1	3.3	2.6
ratio receipts numbers/weight	4.4	3.6	5.3	5.0	2.4	3.0

Table 7.3 Cost return analysis of bait production per cycle

	Level of production				
	80%	**70%**	**60%**	**50%**	**40%**
Variable Costs					
Labour (UShs)	73,500	73,500	73,500	73,500	73,500
Seed (UShs)	1,600,000	1,600,000	1,600,000	1,600,000	1,600,000
Feed (UShs)	96,600	96,600	96,600	96,600	96,600
Manure (UShs)	2,000	2,000	2,000	2,000	2,000
Fixed Costs					
interest investment for construction (UShs)	85	85	85	85	85
Investment Costs					
pond construction (UShs)	125,000	125,000	125,000	125,000	125,000
Total Operational Costs	**1,897,185**	**1,897,185**	**1,897,185**	**1,897,185**	**1,897,185**
Returns based on Fish numbers					
Profit (UShs)	1,302,815	902,815	502,815	102,815	- 297,185
profit (excluding labour costs) (UShs)	1,376,315	976,315	576,315	176,315	- 223,685
returns to investment, farmer's view	81%	56%	31%	6%	- 19%
returns on total investment, economist's view	69%	48%	27%	5%	- 16%
returns to labour (UShs/wd)	28088	19925	11762	3598	- 4565
returns to land (Ushs/m^2)	1,302,564	902,564	502,564	102,564	297,436
break-even price (Fish/fish)	28	32	37	44	55
break-even production (no.)	35,444	35,444	35,444	35,444	35,444
ratio of net profit to operating cost	0.74	0.51	0.28	0.06	- 0.17
FCR	0.8	0.9	1.0	1.2	1.5
Returns based on Fish Weight					
Profit (UShs)	1,315,365	906,495	509,307	112,119	- 296,751
profit (excluding labour costs) (UShs)	1,388,865	979,995	582,807	185,619	- 223,251
returns to investment, farmer's view	82%	57%	32%	7%	- 19%
returns to investment, economist's view	69%	48%	27%	6%	- 16%
returns to labour (Wd/wd)	28,344	20,000	11,894	3,788	- 4556
returns to land (UShs/ m^2)	1,315,114	906,244	509,056	111,868	- 297,001
break-even price (Kg/kg)	22	22	22	22	22
break-even production (kg)	152	152	152	152	152
ratio of net profit to operating cost	0.74	0.51	0.29	0.06	- 0.17

Partial budget analysis

In experiment 1, proportionately fewer gains would be obtained from increasing stocking density, even when fish were priced based on size. In experiment 2, it would be more beneficial for a farmer using only fertilizer as an input (treatment I) to adopt either treatment II or V. However when fish are sold by number, farmers would get relatively more by adopting treatment I (table7.4).

Table 7.4 Partial budget analysis

Treatment	Experiment 1 Net Gains weight (UShs.)	Experiment 1 Net Gains, numbers (UShs.)	Experiment 2 Net Benefit Weights (UShs.)	Experiment 2 Net Benefit Numbers (UShs.)
I				
II	-52,843	71,925	49,009	-40,022
III	-30,214	63,792	-190,489	-92,184
IV	-20,203	58,571	-21,695	-61,489
V	-	-	259,112	-32,665
VI	-	-	-81,317	-103,810

7.3.2. Sensitivity Analysis

Seed

Seed accounted for 51-82% of total variable costs depending on the experimen and treatment. It was the most costly of the operational inputs (table7.5). Seed costs in experiment 1 also accounted for a larger proportion of gross income comp red to experiment 2 (table7.6).

Table 7.5 Variable cost structure of experiments

Inputs	Treatment I	II	III	IV	V	VI
O. niloticus						
% seed	58%	73%	79%	82%	-	-
% feed	6%	4%	5%	5%	-	-
% fertilizer	25%	16%	12%	9%	-	-
% labour	12%	7%	5%	4%	-	-
O. niloticus-C. gariepinus						
% seed	84%	81%	70%	68%	72%	57%
% feed	0%	6%	20%	27%	25%	33%
% fertilizer	13%	10%	7%	3%	0%	9%
% labour	4%	3%	3%	3%	3%	2%

Shadow prices included labour (UShs 750 per work day) and fertilizer (UShs.30/kg) (*see* Table 3.7).

Table 7.6 Cost structure of experiments as proportion of gross income (Receipts)

Inputs	Experiment 1				Experiment 2					
	I	II	III	IV	I	II	III	IV	**V**	**VI**
Sales by Weight										
% seed	60%	94%	91%	103%	12%	10%	11%	10%	7%	8%
% feed	72%	70%	65%	76%	0%	3%	15%	20%	12%	22%
% fertilizer	39%	31%	20%	17%	8%	6%	6%	2%	0%	6%
% labour	18%	14%	9%	8%	6%	5%	6%	5%	4%	4%
Sales by Number										
% seed	21%	21%	21%	21%	4%	4%	4%	4%	4%	4%
% feed	25%	16%	15%	15%	0%	1%	6%	8%	7%	11%
% fertilizer	14%	7%	5%	3%	3%	2%	2%	1%	0%	3%
% labour	6%	3%	2%	2%	2%	2%	2%	2%	2%	2%

Shadow prices included labour (UShs 750 per work day) and fertilizer (UShs.30/kg) (*see* Table 3.7).

In *O. niloticus* monoculture, a reduction in unit seed price of UShs. /- resulted in an increase of 36 – 59% in operating profitability (farmers' assessment of investment), when sales were based on the number and size of fish sold (45 – 31% when produce was priced per kg) (see *appendix L*). The effect of a unit fall in seed price was greater at the higher stocking densities when product was valued per kilogram. In order to compensate for an increase in seed cost of UShs. 25/-, production would have to increase by up to 58% to break-even, depending on the treatment. Returns to investments, land and labour were more sensitive to changes in seed price when product was valued by number and size rather than weight.

The effect of a unit change of UShs. 25/- and UShs. 65/-[6] for *O. niloticus and C. gariepinus* seed prices respectively resulted a change of 45 – 48% and 43 – 50% change in farmers' returns to investment "farmers view" when sales were d ne by number and in kilograms respectively in *O. niloticus-C. gariepinus* polyculture. The effect of change was from 9 – 17% on profits. The magnitude of change in returns was least for the most pr ductive treatments (V and VI). Farmers would need to have an increase in yield to break-even production of 14 –

[6] marginal change of seed price 20% of unit seed cost for *C. gariepinus* and 30% of unit cost for *O. niloticus*

24% to cover a UShs. 25/= increase in seed cost. UShs 25/= represented on average the transport costs farmers incurred to purchase seed.

Feed and fertiliser

In the monoculture experiment, feed in all treatments was less than 10% of total variable costs. When fish were sold by number, a change of UShs 25/- in feed prices resulted in a 2 – 11% change in profits and returns to investment (both farm s and economists view). Production would have to increase by not more than 2% to offset t ginal increase. Returns to investment, land and labour were most affected in treatment II by increases in feed price. Fish sales by weight were less sensitive to changes in feed price for all parameters following similar trends when fish were valued by number and size.

A marginal change of UShs./kg 25/- of feed costs in the polyculture system resulted marginal changes in profits of up to 117% (treatment II) when s les were per head or 279% (treatment IV) by kilogram. The greatest effect on returns was from the treatments that had the highest feed inputs and lowest feed productivity respectively. The corresponding change in break-even production was similarly affected.

Labour

The monoculture experiment was only profitable when costs of labour, capital and land were nil. The polyculture experiment however, registered positive returns when these were given realistic prices or opportunity costs (see *appendix L*).

Percent marketable yield

Leakage and predators resulted in reduced marketable yields. A 20% decline in yield resulted in a 15 – 88% and 5 – 6% decline in returns in the monoculture system when fish were sold per head and kilogram respectively depending on the treatment. The marginal change in returns declined more in treatments with higher stocking density.

In the polyculture system, a 20% decline in yield resu ted in a 48 – 78% and 47 – 110% decline in returns when fish were sold per head and kilogram r pectively. Declines in fish yield had a larger impact on returns to land of up to 100% or more depending on the productivity of the treatment.

Cost of capital

In both experiments, a marginal decline of 10% in interest rates resulted in not e than 1% improvement on profits. In practice, the writing off ond construction costs is a difficult issue, as in many respects it is considered by the far r as a 'sunk cost'. However, if capital has to be borrowed to develop the pond, and based on commercial interest rates of capital (20%) on a loan, aquaculture is currently an unprofitable venture. Returns indicate that there is a big difference between rehabilitating existing ponds and digging new ones even when capital is repaid at 10% interest over 8 months.

Marketable size

A 10% decline in marketable size resulted in a 12 to 7 % decline in returns in the monoculture system when fish were sold by number. In the polyculture experiment, the marginal decline in returns was 14 – 17%.

7.3.3. Risk analysis

The majority of small-holder rural farmers in the country are risk-averse and cannot afford to make a loss on even one year. Hence this analysis based on one production cycle assuming that one production cycle is achieved per year.

Break-even production: Differences between actual yields and break-even production levels were negative in experiment 1, indicating a high risk for unprofitability when fish were valued by weight. In experiment 1, even when inputs and output were costed using on-station costs[7], production would have to increase by 371%, 202%, 418% d 134% in treatments I to IV respectively in order to achieve the minimum acceptable ratio of profit (benefit: cost ratio 1.5) to operating cost per cycle by small farmers,. This would be practically impossible with the given the quality and levels of inputs used, even if there had been no leakages. There was definitely less room for failure in *O. niloticus* monoculture (experiment 1) compared to polyculture (experiment 2). However, when break-even production was assessed in terms of number of fish (where sales would be by number and size), *O. niloticus* monoculture and *C. gariepinus* bait production offered wider safety margins than *O. niloticus*- *C. gariepinus* polyculture (table 7.7)

Table 7.7 Safety Margin (%) between Actual and Break-Even Production

Experiment	Treatment					
	I	II	III	IV	V	VI
Yield Valued by Weight						
Experiment 1: *O. niloticus* monoculture	-62.8	-66.7	-64.5	-69.3	-	-
Experiment 2: *O. niloticus*-*C. gariepinus* polyculture	55.2	44.5	33.0	29.4	51.6	44.0
Break even yield as percent stocking density						
Yield Valued by Number And Size						
Experiment 1: *O. niloticus* monoculture	75.0	53.0	51.0	70.2	-	-
Experiment 2: *O. niloticus*- *C. gariepinus* polyculture	13.3	15.0	20.2	22.8	21.6	27.2
C. gariepinus bait production	43.1	43.1	43.1	43.1	-	-

Production by numbers was based on 80% percent yields.

Differences in break-even production were also affected by leakages, effects of application of manure and seed: analysis of these was beyond the scope of the research.

[7] On-station costs refer to costs at which inputs were purc ed for use in the experiments at the Aquaculture Research and Development Centre, Kajjansi as opposed to the costs o hese inputs for farmers in the different AEZs.

Break-even price: Farmers would be better off buying fish from the mar et than producing it themselves in productions systems like experiment 1, if fish were valued by weight . At a market price of UShs./kg 1,200/- on-station, their safety margin in case of price fluctuat s or falls in production would be only 8%. Experiment 2 and bait production, had higher safety margins for all treatments. Hence farmers had greater leeway for variations in market price and fluctuations in production. They would even be able t give more fish away for free to meet social obligations.

Table 7.8 Safety margin (%) between market price and xperimental break-even price

Experiment	Treatment					
	I	II	III	IV	V	VI
Yield Valued by Weight						
Experiment 1: *O. niloticus* monoculture	8.3	-2.4	4.3	-10.7	-	-
Experiment 2: *O. niloticus*- *C. gariepinus* polyculture [a]	69.9	69.5	54.9	52.7	68.1	56.8
Yield Valued by Number And Size						
Experiment 1: *O. niloticus* monoculture	5.3	33.3	35.7	34.3	-	-
Experiment 2: *O. niloticus*- *C. gariepinus* polyculture[b]	83.3	81.2	74.8	71.5	73.0	66.1
C. gariepinus bait production	44.0	36.0	26.0	12.0	-	-

[a] Unit weight of fish from experiment 2 based on proportion of total yield that was *O. niloticus* or *C. gariepinus* and appropriate costs were attached (UShs./kg 1,200/- for *O. niloticus* and UShs./kg 1,500/- for *C. gariepinus*).
[b] Unit cost per fish in experiment 2 based on average of number and size of each of the species stocked, at original stocking density (UShs 1,000/-).

7.4. Concluding remarks[8]

7.4.1. Production

Experiment 1

Total yields per cycle per year were lowest from *O. niloticus* monoculture compared to polyculture (experiment 2) for all treatments. They were also lower than for *C. gariepinus* bait

[8] It should be noted that, ultimately, a complete factorial design needs to be conducted testing the variables (stocking density, feed, fertiliser) with both species. In view of the complexity of polyculture, more studies are required covering more permutations and factors, in order that more comprehensive recommendations can be made.

production. Total net yields were lowest at 1 fish/m^2, though fish were largest at this density. Glasser and Oswald, (2001) in their studies on the effect of high stocking densities on *O. niloticus* yield under extensive culture conditions in Côte d'Ivoire found similar results. By simulating stocking density on net yield by successively imposing duration of rearing period and fish market-size target as constraints they found that maximum yields were obtained when organic input was fixed at 0.4 to 0.5 fish/m^2. Yields at this stocking density were three times higher than yields at 3 fish/m^2 and more than 50% higher than yields obtained at 2 fi h/m^2. Based on results conducted both on-station and on-farm, they found that it was impossible to obtain market-sized fish under low-input culture at 2 fish/m^2, even after a 300d rearing period. The authors explained the effect of stocking density o net yields to be due to increased competition for food, especially protein, in ponds whose major input was organic matter. This competition resulted in reduced growth and higher relative maintenance needs. They also attributed this trend to Hepher's hypothesis on the inverse relationship between increasing body weight and relative maintenance needs which, according to formulae of maintenance rations indicated that the carrying capacity for 400 g fish was, for example, 39% higher than that formed by 200 g fish.

Experiment 2

While rearing periods differed between experiments, findings by other r searchers confirmed that *O. niloticus – C. gariepinus* polyculture resulted in increased production per unit area under similar conditions to *O. niloticus* mixed sex monoculture (de Graaf *et al*., 1996; Teichert-Coddington, 1996; Fischer and Grant, 1994). In comparative studies between *O. niloticus* mixed sex monoculture and *O. niloticus – C. gariepinus* polyculture, de Graaf *et al*., (1996) found that over a 200 day rearing period polyculture in experiments fed with wheat bran at daily rates of 4-11% body weight, net yields (kg/ha) were not significantly different between experiments. They obtained net yields of 3,380-4814 kg/ha and 3,891-4,953 kg/ha in *O.*

niloticus monoculture and in polyculture experiments respectively with increased feed input, depending on the size of the predator at stocking. In *O. niloticus* monoculture yields of 1,274-2,929 kg/ha over a 145-day cycle in ponds receiving both feed and fertilizer were obtained by Green *et al.* (2002). The authors found that yields were highest in ponds with organic fertiliser and formulated feed and that in the case of *O. niloticus* monoculture, semi-intensive systems had higher average returns per kg yield than extensive sy ems. In extensive systems, the production potential of mixed-sex *O. niloticus* was limited because of excessive recruitment that resulted in harvests where 28-70% of the total biomass consisted of low-value fingerlings rather than that of stocked fish (de Graaf *et al.*, 1996). This results in reduced food availability in ponds.

Average fish sizes and uniformity were higher in exper ment 2 than experiment 1. Several authors have found that larger tilapia are obtained from predator-prey culture than monoculture in tropical ponds using low quality inputs (de Graaf *et al.*, 1996; Fischer and Grant, 1994). Growth rates of tilapia increase in the polyculture experiments because it eliminates the negative effect of fingerling biomass on feed availability within the pond system. De Graaf *et al.*, (1996) noted that when the fingerling population constituted over 25% of pond biomass (w/w) in an *O. niloticus* mixed sex system, production was interfered with because of competition for feed. When a predator was added to th stem, fingerlings were converted to an equal or higher biomass of *C. gariepinus* and feed availability to the stocked fish was increased. They concluded that stunting of fish in *O. niloticus* monoculture was primarily due to husbandry practices and consequent limitations on s tem carrying capacity rather than the species itself.

It should be noted though that fish growth rates in fa mers' ponds (see table 7.9) were several hundred times less than those achieved in the experimental ponds, even under *O. niloticus* mono-culture. The use of one or two species is therefore not in itself the only remedy needed for farmers' management regimes.

7.4.2. Efficiency of feed- fertiliser utilisation

In the *O. niloticus-C. gariepinus* experiments, the productivity of both feed and fertilizer was improved. The improved level of efficiency can be att ibuted to the fact that in ponds with heavy supplemental feeding, natural food organisms typically account for 30-50% of tilapia growth, whereas only 5-10% of catfish growth is due to ingestion of natural food organisms (Teichert-Coddington *et al*., 1997). Hence, *O. niloticus* performed better in treatments with higher input levels of fertilizer and *C. gariepinus* in treatments where feed input was high. Feed utilization by *O. niloticus* in low input systems is often low because of the poor quality of available feeds. Under such conditions *O. niloticus* tends to prefer phytoplankton, then detritus which are products of fertilization to supplemental fe (Jamu and Piedrahita, 2002). Yields of *O. niloticus* in fertilized ponds therefore correlate positively with net primary productivity (Yi, 1998).

The results showed that in *O. niloticus-C. gariepinus* culture, at different input levels of feed and fertilizer, total pond production was better optimised which reduced the risk for farmers of reduced yields and returns. This was important becaus dequate feed and fertilizer supply for aquaculture were constraints for farmers. The farmers also indicated that by varying these input levels, the production of either of the species could be enhanced depending on local market preferences. Thus in Western Uganda where animal manure was more available and local markets favoured tilapia, *O. niloticus* yields would have an advantage in the system. In the East of the country, where availability of cereal and grain residues was higher and that of animal manure lower, yields of *C. gariepinus* would be higher. *C. gariepinus* was also found to be culturally among the most preferred fish species in the East.

7.4.3. Economic returns

Higher economic returns from the polyculture experimen s can be attributed to effects on pond carrying capacity as a result of reduced fingerling population and consequently increased food availability for stocked fish. This resulted in comparatively higher overall growth rates (table 7.9). The loss in fish biomass by stocking fewer *O. niloticus* per unit area and through predator control was economically compensated for by larger tilapia that fetched a higher price (Glasser and Oswald, 2001; de Graaf *et al*., 1996). In addition, fingerlings were in the latter case converted to a more marketable product, *C. gariepinus* (Fischer and Grant, 1994). Since fish are always marketed based on unit size, this is a important determinant for potential returns. Production and returns were also affected by sp potential and prices of each of the species. Higher profits, returns to investment, labour and land were consequently obtained from polyculture (experiment 2) and bait prod ction than *O. niloticus* monoculture (experiment 1).

Table 7.9 Comparative growth rates and feed conversion efficiencies

System	Feed: DM input ($kg/m^2/y$)	Feed: CP Input ($kg/m^2/y$)	Fertilizer: % N Input	Net yield ($kg/m^2/y$)	Growth Rate(g.d-1)	FCR
O. niloticus						
Farmers						
BMC	6.49	1.24	0.04	0.19	0.0005	830±574
WBC	0.26	0.02	0.01	0.17	0.0005	68±97
MAIBC-FS	0.88	0.05	0.08	0.4	0.0011	59±87
Experiments						
I	0.19	0.02	0.04	0.21	0.33	0.56± 0.25
II	0.23	0.03	0.04	0.24	0.41	0.78± 0.09
III	0.36	0.05	0.04	0.38	0.64	0.58± -
IV	0.52	0.07	0.04	0.46	0.76	0.61± 0.11
O. niloticus - *C. gariepinus*						
Farmers						
BMC	9.98	0.57	0.03	0.32	0.0009	651±1003
WBC	1.84	0.14	0.02	0.001	0	880±1560
MAIBC-FS	8.59	0.24	0.11	0.26	0.0007	1979± -
Experiments						
I	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.64	0.87	0.0 ± 0.0
II	0.45 ±0.2	0.1 ±0.00	0.04 ±0.2	0.73	0.99	0.5 ± 0.2
III	1.83 ±0.4	0.24± 0.1	0.03± 0.0	0.65	0.88	2.1 ± 0.5
IV	2.52± 0.6	0.33± 0.1	0.01± 0.0	0.09	0.94	2.8 ± 0.5
V	2.20± 0.5	0.29± 0.1	0.00± 0.0	1.12	1.33	1.6 ± 0.3
VI	3.69± -	0.48 ±-	0.05± -	1.05	1.43	2.6 ± -
C. gariepinus Bait (% yield)						
80%	2.53	0.98	0.02	2.3	3.2	
70%	2.53	0.98	0.02	1.9	2.6	
60%	2.53	0.98	0.02	1.4	2	
50%	2.53	0.98	0.02	1	1.4	
40%	2.53	0.98	0.02	0.5	0.7	

7.4.4. Effect of unit of product sales

The results indicated clear advantage when fish were p ed by size and number rather than unit weight. This means consumers may be paying much highe prices for small fish, the reasons for which were beyond the scope of the study to determined. They also indicated that management factors for both experiments influenced individual sizes of fish more significantly than they influenced pond biomass and hence the management factors were more important determinants for profitability.

This observations on the effect of fish size on profitability suggests experiments should be aimed at optimising by number, not weight particularly for that for farmers targeting local markets in the country. Scientific analysis by weight, but is therefore irrelevant to farmers who only sell by number. The observations also highlight:

i. the difficulty of doing economic analysis in an economic environment when marketing and prices are unstructured and variable

ii. that economic productivity can depend more upon how the farmer sells their fish rather than how they grow them. Training on this must herefore be included in extension.

The importance of understanding the actual possibilities open to farmers for formulating clear recommendations is seen by the complex interplay of stocking densities, input man ement regime and growing period: this interaction in turn needs interpreting in the light of actual market options. So, for example, since price per unit weight can be higher where fish are priced per fish (if they are of a small but favoured size, chapt), sales by number and size can favour the farmer as long as the percentage of marketable yield is high. The importance of good management for quality yield becomes greater when stoc ng densities are increased. In the case of monoculture, management of inputs is critical chieve high quality and this can be beyond the capability of most farmers. In that case, could be advisable for them to stock at lower densities. Faster growth rates (with low management) could still allow them more than one crop a year, which would compensate for the lower stocking density. The experiment showed that there may not have been be any effect on f sh size (the experiment showed no statistical difference) if farmers increased inputs (maize bran, cow dung, and stocking rates) in *O. niloticus* monoculture. In this case, it could be assumed that s long as the minimum marketable sizes were obtained, at increased stocking ensities increased numbers might be able to compensate for the lower prices received from smaller ish. Reaching this minimum marketable size however, may require longer production cycles, allowing only one crop a year. In view of the discussion and management options identified above, this possibility was limited. The findings also suggest the limitations of one-size-fits-all sets of recommendations for *O. niloticus* monoculture.

7.4.5. Returns to investment, farmers vs. economists view

Returns to investment have been presented in what have loosely been called a "farmer's view" and "an economist's view". The economist's view shows e profitability in purely financial terms from a single "end view" perspective. However, f rmers are also influenced in their analysis of investment by <u>how</u> and <u>when</u> investments are made. Farmers' perceived returns to investment seem to be based mainly on the price paid f r seed, their most significant capital (cash) expenditure in fish farming. Small but regular inputs (including time for pond management) which can be found from the farm/household do have a value (either pr ce or opportunity cost), but farmers seem to be more prepare o make these investments since no single large outlay is involved. In most cases, they constructed fish ponds on land they already owned using family labour. (Where these factors were constraints, they often formed groups. Farmers who hired labour to dig a pond would certainly have a different calculation on the profitability of those ponds.) Again, although labour and land have a value, where there is no single outlay of cash, a farmer may give a different economic value, or at least show behaviour which expresses a different value given to such non-cash "investment". Farmers can therefore sometimes be found behaving in ways which, from a purely economic perspective, could seem "irrational", and this may explain why fish farming has continued despite the fact that, according to economists, it may be unprofitable. This analysis of "a farmer's view" is presented only as a rough attempt to analyse investments in another way, rather than to present a definitive equation on how all farmers perceive investment and returns to investment. Since investment decisions in fish farming systems are usual y farmers according to whether they "feel" profitable, rather than on book-keeping profit and loss accounts, research and extension needs to understand how different regimes may be perceived. Further study and analysis of farmers' economic decision-making, which would be necessary to refine this analysis, were beyond the scope of this research.

In conclusion, the results show that polyculture (experiment 2) is more productive both biologically and economically. Production of *C. gariepinus* as bait also presents a more productive and profitable option than *O. niloticus* monoculture. However, the results also highlight, by comparison, the very low growth rates th farmers are currently achieving, which explains the fact that so few of them have ever bothered to harvest their ponds. Attention to the factors outlines in this chapter, therefore, offer the potential for improvements in the efficiency of pond culture on the scale of orders of magnitude.

CHAPTER 8

Discussion and conclusions

8.1 Overview of results

The results have shown how the interaction of factors endogenous and exogenous to the farm, inter-dependently affected pond production and returns.

8.1.1 Influence of socio-economic factors

Fish farming was adopted by both rural and urban farme s in the Lake Victoria Basin, largely for economic reasons. It was basically one among the several ro es through which farmers put to use the productive assets they had access to in order to improve their livelihoods and/or to trade up assets (Ellis and Bahiigwa, 2003). Hence, by farming fish, farmers hoped they would have a cheaper and more easily accessible source of animal protein, earn income and eventually acquire higher value livestock or even more land. The relative importance of these objectives var ed, depending on the structure of the fish farming unit, between units and on the assets possessed by the farmer.

Farmers in the area invested an array of resources in aquaculture, the levels and quality of which varied, according to their personal capabilities. The levels and quality of resources invested into aquaculture by farmers was found to be significantly influenced by their location. Investment capital for farmers was in the form of cash and non-cash capital obtained from their own savings, accruing to t ir other farm enterprises and off-farm employment. The study showed that financial assets were not the most critical for all aspects of investment, but finance for farmers was most critical for purchase of seed. Pond construction depended more on the natural assets armers had (notably adequate and suitable land), and their social and human assets (their ability to find labour). Pond management depended more on the farming environment, a d on social and human assets. Allocation of these resources for aquaculture depended on the farming units' overall livelihood objectives.

According to Bebbington, (1999), where people's liveli ods have shifted from being directly based on natural resources to being based on range of other assets, income sources and markets, it becomes important to have a wide concept of the resources that they need to access in the process of 'composing' a li elihood. In this study, a range of kinds of capital or assets needed for aquaculture were considered and how access to these might affect the viability of the farming of *C. gariepinus* for farmers.

Labour and land

Farmers gained access to labour by mobilising household labour, workgroups or hiring labour. Hired labour was depended upon by fewer farme s and it was mainly hired for pond construction. Most depended on household or group labour. Much of the labour was therefore not costed by farmers in monetary terms. Such labour, however, did have significant opportunity costs for farmers, because its availability was affected by local labour markets and farmers' alternative livelihood options. Consequent the persistently poor returns to investment which farmers ere obtaining from aquaculture resulted in human, physical and financial assets being reallocated to other enterprises. This was obviously apparent where farmers utilised the land around their ponds for vegetable, livestock (in paddocks), paddy rice, coco-yam and sugarcane production that were more profitable. At peak demand for labour on-farm, fish ponds were consequently also less well managed.

Willingness to take risks

Despite the continued inability of aquaculture to meet farmers' objectives, fish farming in the Lake Victoria Basin has continued, with even new farmers picking it up. It was practically impossible for disappointed farmers to get rid of an already excavated pond. At the worst, they completely neglected their ponds and they let them become overgrown with bush. However, many of the farmers had persisted in farming fish because they still believed that local market potential was good and that aquaculture could be a potentially profitable enterprise "if only y could just get it right". The results showed how farmers reached this conclusion bas d on their perception of financial investment that was associated primarily with large cash outlays to procure seed and/or construct ponds.

Some farmers had therefore out of their own accord, st rted to seek options that could improve their production. Thus farmers for whom *C. gariepinus* hatcheries were accessible had already started to adopt polyculture before official guideline had been released from the Aquaculture Research Station, Kajjansi. The research showed that such farmers were often wealthier and hence could afford th risk of adopting *C. gariepinus,* even without having examples of success. Some farmers had also started trying out other species, the choice and pond management regimes of whi were sometimes influenced by fishermen's observations of these species in the wi A few farmers had also started monitoring what their fish preferred to eat. Attempts were also made at improvising fish harvesting gear. These attempts highlight the value o farmers' human and social assets in developing new knowledge to overcome their constrai ts. This again proves the point (Sumberg and Okali, 1989) that research institutions a wrong to see farmers only as consumers of ideas produced by scientists. Research n eds to harness this ingenuity.

The importance of farmers' human and social assets in nfluencing adoption, managerial ability and agricultural productivity among rural farm s has been reiterated by several authors (Panayatou *et al.*, 1982; Yang and An, 2002).

Markets

Agricultural markets also influenced the availability f inputs for aquaculture. The net flow of agricultural produce to and from an area as a result local market transfers affected local supply and costs of cereals, fish meal nd oil-seeds in particular. Consequently, there was a greater variety of feed and fertiliser inputs locally available to aquaculture and in more substantial amounts in Kampala and Wakiso Districts, as long as farmers had disposable cash. The application of input farming in both the urban and rural areas was subsequently influenced by competi demand for these inputs by farmers' other agricultural enterprises. Hence the po r performance of aquaculture resulted in ponds receiving the least agriculturally competitive inputs.

8.1.2 Influence of production factors

Seed

The most critical limiting physical factor for farmers was access to seed. (It should be remembered that this research had intended to conduct on-station polyculture experiments, but had failed to find sufficient seed of *C. gariepinus*. One would assume that the difficulties facing farmers in accessing seed are even greater.) Low availability and high cost has led farmers to obtain seed from vari us sources, and to stock seed of different sizes and unknown quality. As a result far ers under-stocked their ponds and/or stocked them over a period of time in an inconsistent fashion. This was found to have had a profoundly negative effect on production and resulted in a high oportion of unmarketable yield. Clearly because of constraints in access to seed, and the consequent inadequate stocking practices, the performance of fish ponds was compromised the very start, both in terms of yield and returns. The r urns were affected not only by the low yield and poor marketable quality. The relatively high allocation of financial resources to seed compounded with the negative impact current seed utili ation practices are having on yield shows how the lack of locally prod ced seed is resulting in enterprise failure.

The demand for seed (as bait) not only affected fish f but also capture fisheries. Indications were that fishermen might require anywhere between 4-24 million fish as bait per year. The current demand is being obtained from the wild. From an ecological point of view it would be not sustainable to continue obtaining such quantities from the natural waters, particularly when the sustainability of fishery yields and diversity is being questioned (World Bank, 1991; Kaelin and Cowx, 2002). demand for bait offers an opportunity for farming which the study showed could be feasible. For farmers, the potential benefits of farming bait would include increased productivity and profitability of particularly small ponds. Taking into account trad ekly bait demand, bait would more likely be purchased as a single crop (even in remote areas). Demand is year round, though with some seasonal fluctuations.

Feed and fertiliser

The other primary inputs (feed and fertiliser, and lab used for fish farming were derived from the farm or other agricultural by-products. Consequently the supply and demand for these inputs was influenced by local farming systems, trade in agricultural produce and local labour markets. The fact that agric e was exclusively rain-fed resulted in the pronounced seasonal effect on local av ability, supply and cost of these inputs. Similar findings have been found in studies a essing input use and rain-fed rural agriculture (Alwang and Siegel, 1999; MFPED, 2000). eed and fertiliser management subsequently varied in response to these factors depending on farmers' priorities.

A great deal of literature exists showing the increase in productivity from fish ponds by using different types of animal wastes as fertiliser (Athithan *et al.* 2001; Moav *et al.*, 1977; Prein 2002;, Gupta *et al.*, 1985; Banerjee *et al.*, 1979; Fagbenro and Syndenham, 1988, Chellapa, 1996). Experiments conducted by Duan (1998) on carp-polyculture in integrated fish farming indicated that 2 cows were required to adequately fertilise 0.13 ha of fish pond stocked at 9,825-14,295 fingerlings/ha.; 8 pigs were needed for the same area stocked at 13,500 fingerlings/ha, or 760 chickens at 14, 805 fingerlings/ha. Rahman (1998), obtained favourable results with 500 broilers hectare of pond area stocked with 6000 carp/ha.. Although many farmers do not have sufficient livestock, many farmers in the study did have livestock in numbers which would ***in theory*** provide manure rates comparable to these. Extension in Uganda has therefore concentrated on trying to persuade farmers to use this potential resource to improve pond productivity but, as this study found, with little success. There are tw easons why even farmers who own livestock use little manure on their ponds, as a farming systems perspective makes clear. First, farmers in the Basin require their manure first for crops and only secondari for pond production. This is based on a rational calculat of the comparative economic returns per unit of manure from different uses. Retur from manuring ponds may be worthwhile in experimental conditions, but have not been from farmers' management systems. Secondly, both livestock and fish management systems vary greatly. In the Basin, most livestock are kept in extensive systems, r ging freely. This means that the amount of manure which can actually be easily collected is low, and the quality of the manure (in terms of % N) were lower than values found by other authors (e.g. Lin *et al.*, 1997), presumably because of nitrogen evaporation from poor managed manure. Just as importantly, few of the fish ponds visited in this study were near the homesteads, but were situated in the valleys in or near wetlands. Thi makes it difficult to physically transport the manure to the ponds, and costly in terms of labour if this can be accomplished. It is easier simply to use the manure on vegetables growing around the house.

It was only in Kampala and parts of Wakiso District, where intensive livestock production was more common and farmers had smaller are of land, that it would be possible to generate the comparable amounts of manure at the recomme d frequencies for fish farming throughout a production cycle. One response to this in Africa has been to move towards lower grade inputs for which there is ess competition from other uses (Chuikafumbwa *et al*., 1993, Chuikafumbwa, 1996). Even here there may be consideration of the labour input necessary. This is cially true where it has been found, for example, that Napier grass needs to be chopped before it is applied (Chuikafumbwa, 1996) in order for yields not be decreased.

8.1.3 Influence of bio-technical factors

Input and management practices varied between farmers. Few farmers were able to provide the same level of management consistently during the production cycle, because of the constraints they faced in accessing inputs. These constraints were linked to aquaculture's lower priority because of its failure to meet their material and economic objectives. This further increased the likelihood of ntinued poor yields and low reliability of production. Levels of feeding and fertilisation e based on input availability at a particular time rather than on a planned strategy. As a result, feeding and fertilisation application rates for most farmers were often sub-optimal.

Under ideal conditions, levels of supplementary feeding are based on the suitability of the feed for the species stocked, stocking densities, age fish and physico-chemical pond water characteristics (Jauncey, 2000). The commonest feed inputs used by farmers had high crude fibre levels. High dietary fibre in a feedstuff (even where other nutrient values are good) lowers feed utilisation for most fish s by diluting digestible nutrient densities (Jauncey, 2000; Maina *et al.*, 2002; Rojas and Verreth, 2003). Fertilisation levels should also be based on the nutritional requirements of species stocked, stocking densities and on the type of fertiliser. Fertilisation is also supposed to be done in consideration of local environmental factors (such as light intensity and duration, ambient and/or water temperature, soil and water quality), pond depth and even the frequency of its application, all of which are known to influence i efficacy (Garg and Bhatnagar, 2000; Soliman *et al.*, 2000; Lin *et al.*, 1997; El-Sayed, 1996; Yi *et al.*, 2003; Green *et al.*, 2002; Lin *et al.*, 1997). Inputs like rice bran, which are rich in phosphorus but whose palatability for tilapia is low because of high crude e levels, have been shown to improve yields as a result of a fertilisation effect, as phosphorous is commonly the limiting factor of productivity in ponds (Glasser and ald, 2001; Rojas and Verreth, 2003). Hence, the question of efficacy of some farmers' inputs as feed rather than to supplement fertilisation may also be raised. Feeding and fertilisation need to be taken considered together for successful pond management.

The commonest fish farmed in the Lake Victoria Basin was tilapia. Both survey and experimental results indicated that tilapia yields were low, mainly as a result of management factors (detailed above) rather than due to inherent species characteristics. The introduction of *C. gariepinus* into the system vastly improved yields, but the effect on economic returns was even greater. This was due to three factors: the tilapia production was improved, because more fish grew to mar able size, because of population control; *C. gariepinus* is a more valuable species because it tends to grow much larger; and the polyculture combination improved the efficiency of input utilisation, so that the combination was greater than either would ve been individually.

8.2 Sustainability and adoption

8.2.1 Overview

The above discussion shows how intertwined and varied e multiple factors affecting production were. The results also highlighted the fact that farmers allocated resources to specific enterprises in order to best meet their overall livelihood objectives from their economic activities as a whole, rather than to optimise returns from specific livelihood strategies. Similar observations have been made by Hishamunda *et al.* (1998) among smallholder fish farmers in Rwanda. The authors noted that smallholder fish farmers weighed economic benefits from their farm activities based on highest income above cash expenses from the farm by value of the resources at hand. The apparent under-utilisation of resources for aquaculture among farmers was in fact the reallocation of scarce resources to farmers' other livelihood activ ties that translated into positive net benefits to overall livelihood objectives. Farmers, more often than not, had limited rather than necessarily under-utilised or inefficiently utilised resources.

The limited access to resources for fish farmers was found in the study to be associated with poor pond performance. Not all these limiting resources may hav been directly required for aquaculture but their scarcity affected a culture production, in as far as overall household objectives were affected. Limited a cess to resources by rural farmers is known to constrain greatly the viability of their economi activities (Bebbington, 1999). In addition, it should be appreciated that far ers relied heavily on their internally available resources to improve productivity within the limits of their assets (Ruben and van Ruijven, 2001). Consequently, in order to identify and develop the potentially most useful technological options, it is important to have clear sense of the most important assets for different people in different places, toget r with the factors governing the access and use of these assets to build livelihoods (B 999; Allison and Ellis, 2001). The willingness of farmers to adopt and sustain alternative fish farming techniques will be affected not only by their expectations for increased income or output, but also on their resource constraints and the ability of the proposed technology to alleviate prevailing production constraints (Doss, 200).

Gebremedhin and Swinton, (2003) in their study on rural farmers' investment on soil conservation technologies in Ethiopia, found that ther were different factors which affected the probability of farmers adopting new practices from those which affected the intensity with which they adopted them. These were two separate decisions, often made at different times. Aquaculture research and extensio Uganda have not been based on this kind of awareness. Whether farmers first experiment with aquaculture or a new technology and what they then go on to do are two proc es, which need supporting in different ways. An understanding of the decision making processes involved in both processes is vital for sustainable improvements in the sector to be achieved.

8.2.2 Socio-economic factors

Commodity prices, market development, labour markets, perceived risk and economic returns to land and labour are among the major socio-economic factors that affect the adoption and sustainability of agricultural technology (Green et al., 2002).

Markets

Markets and market transaction costs have far reaching implications on agricultural production and productivity. They affect farmers' choice of technology, investment levels, and their access to, and use of, inputs (Deininger and Okidi, 2002; Alwang and Siegel, 1999; Stifel *et al.*, 2003). The market dictates what commodity a farmer should produce, how much of it should be produced and what th costs of production should be if the farmer is to get reasonable profit (Shang, 1990 Hau and von Oppen (2002) noted that, as a general rule, good market access leads farmers to produce high value commodities for which they have comparative cost advantage. Low value and storable commodities tended to be produced in more remote areas. According to Stifel *et al.* (2003), in agriculture, the incidence of income poverty tends to increase with remoteness, yields drop as one gets further away from major market , and the use of agricultural inputs declines with isolation. Similar findings have been found in Uganda by Deininger and Okidi (2002) in their study on capital market access, factor demand and agricultural development in the rural areas of Uganda. In Uganda, 0% of producers still live at, or close to, subsistence levels, because their remote loc tion means they have a limited response to larger and more lucrative market signals. They thus tend to have a higher proportion of their crop mix focused on non-tradables. This, according to the authors, limits their scope for expansion and results in the relative stagnant state of rural economies.

Producing fish as an alternative marketable product therefore offers oppor unities for diversified farm income. However, in remote areas, while there may be a demand for fish, the consumption capacity of rural markets is oft n limited (Glasser and Oswald, 2001). Thus production cycles may be longer, as farmers may not be able o sell all their stock within a short period. Farmers would be more likely to adopt less capital intensive *C. gariepinus* production strategies, as their costs of production would have to be congruent with the purchasing power of local consumers. In more remote areas off major road networks, if farmers want to obtain higher prices they would have to ferry their produce to local major markets, rather than sell at the farm-gate. Such markets are often not very accessible for farmers (taking into account available rural transport). Distances to general markets are likely to be even greater for fish farmers, because ponds tend to be located down in valleys close to wetlands or other wat r sources. Fish spoilage is therefore a possible risk for fish farmers in remote locations intending to sell fresh fish to general markets, especially when one remembers that 15-40% of fish harvested from the lakes is lost due to spoilage along the marketing chain, even though major landings are linked to better transport networks (NRI/IITA, 2002).

For remotely located farmers within easy reach of land ng sites, it might therefore be a more appropriate response to opt for bait production (or better still, a system incorporating both bait and food production to suit local m requirements) rather than produce only food fish for the same market. Here they would have a greater comparative advantage and it might be more profitable for them to ell bait and then purchase fish for their household requirements.

The markets not only influence farmers' income levels but also their access to inputs. As has been cited earlier, the most limiting input to aqu ulture in the Lake Victoria Basin is currently seed. There has long been a deficit in supply from traditional government sources. Current government policy is to divest seed production and supply to the private sector. However, this vacuum is yet to be filled by t private sector. This is may be partly due to limited skills among potential seed producers, but could also be due to real fears about whether the sector – and hence their investment – will actually succeed (Dorward *et al.*, 2004). Consequently, limited access and resulting gh costs have led to stagnation of the sector and to lower, or haphazard, stocking rat Growth and the partial intensification of fish farming, therefore, risks being an unsustainable rural development strategy as long as there is inadequate in stment in seed and other inputs (Reardon *et al.*, 1997; McMillan and Masters, 2003). Strengthening the human capital of seed producers is important, as local availability of ffordable and good quality seed is indeed a catalyst for developing sustainable fish farming (Boehringer and Ayuk, 2003; Little *et al.*, 1996).

Capital

Economic considerations for selecting a farm enterprise include potential economic returns, economic and resource use efficiency, and the farmer's access to operating capital (Green *et al.*, 2002). Access to capital, notably land, labour and finance, are among the critical productive assets for rural farmers. According to Hoe tra, (1994), the key endogenous factors that affect the economic viability of smallholder agriculture are the management capability of farmers, labour costs (monetary/non-monetary) for establishing and maintaining the system, and the cost seed. It is the opportunity costs of land, labour and capital which are important for farmers. Where opportunity costs for land are high, farmers are less willing to invest in enterprises of low productivity. Likewise, if labour markets are not well developed and labour costs are low, farmers can afford to use labour intensive technology. Intensity input use among smallholder farmers is therefore influenced by the opportunity cost of land and/or labour on the one hand, and the expected return from investment on the other (Gebremedhin and Swinton, 2003; Doss, 2001).

Costs of establishment are influenced by the establishment method, choice of species and management practices (Hoekstra, 1994). For example, findings from chapter 7 suggest that unless fish farmers depend on social capital to procure labour for pond construction, *O. niloticus* monoculture is not a viable option under prevailing c ditions. However if rice farmers wanted to farm fish only for household consumption (i.e. small unmarketable fish would be acceptable), adopting rice-fish culture would reduce their costs for pond construction, improving the viability of *O. niloticus* monoculture. It may also be possible to grow *O. niloticus-C. gariepinus* in paddies with positive results (d'Oultremont and Gutierrez, 2002). Where opportunity costs for land are high, farmers are less willing to invest in enterprises with low productivity. Results owed that for pond systems in the Lake Victoria Basin, adding *C. gariepinus* to their fish production systems made fish farming more competitive in terms of returns to labour and land.

Rural farmers' earnings in the country are often unsta and unpredictable due to the dependence on rain-fed production and the subsequent effects of climatic atterns on production. Fluctuations in prices of agricultural pr e, particularly crops, are also unpredictable (MFPED, 2000). Consequently, more farme are having to seek off-farm income that is limited in the rural areas (MFPED, 2000[2]; NEMA, 1999). Doss (2001) estimated that 22-93% of total rural incomes across Africa are now from n-farm. However, this study found that much of the investment aquaculture from the Lake Victoria Basin was still associated with returns from gricultural production – directly from farm sales or from rural employment in the sector. As long as cash flow structures for rural smallholders remain precarious, enterprises ose budgets have a high cost ratio will be unsustainable. This is heightened by the fact that production credit is at present largely unavailable to fish farming, and the cost of c pital is high. The cost of capital in Uganda for farmers from micro-finance institutions ranges from 4-7% per month, which is equivalent to 60% to 125% APR (or at least 50-115% APR in real terms). The minimisation of production risks and insecurity of income therefore has great implications for farmers' livelihoods. The economic role of a technology and assets in a farmer's overall livelihood strategy should therefore e appreciated. Recommendations and evaluation of technologies should be based on unde tanding whether farmers' investment objectives are risk-neutral and profit maximising, or risk-averse and utility maximising (Peterson *et al*., 2002; Goletti, 1999).

In view of farmers' resource limitations and production constraints, if *C. gariepinus* production is to be sustainable, production practices and return hould place fish farming in a competitive position in order to attract investment (Hishamunda *et al*., 1998; Machena and Moehl, 2001). In addition, production patt rns should be targeted at market and economic variables that are most sensitive to profitability indices (Head *et al*., 1996, Setboonsarng and Edwards, 1998).

8.2.3 Environmental factors

In view of the fact that most rural farmers may not afford technologies whose cash outlays are large, appropriate *C. gariepinus* technology demands variable cost-structures with minimum cash outlays. Optimising on-farm resources as inputs for farmers remains the most feasible option. It would en them to save, and offers a cheaper source of investment capital. Saving on expenditure of inputs up to the tune of 40% of gross farm income has been found among small-scale Asian farmers (Lightfoot *et al*., 1994). Hence, the agro-ecological zones, agricultural practices and productivity that influence local agricultural potential are important a they determine the levels and quality of local inputs accessible to farmers (Soliman, 2000; Machena and Moehl, 2001).

Fish performance is strongly linked to environmental c aracteristics. Temperature, for example is a major metabolic modifier for fish (Ross, 00). Consequently, altitude influences the duration of production cycles, feed and manure input levels and efficiency of utilisation in pond production systems (Balarin, 1985). In the higher altitude WBC Farming System, growth rates are therefore likely to be slower. Optimal growth temperatures are above 20^{o}C for both *O. niloticus* and *C. gariepinus* (Anquila-Majarezz and Nath, 1998; Ross, 2000).

Thus the biological and socio-economic performance of aquaculture is limited by physical determinants (Alwang and Siegel, 1999). As fish farming among the majority of farmers is limited to extensive (and in the future, perhaps semi-intensive) production technology should be designed based on local environme al factors in such a manner that management of these resources is optimised (GAMBAS, 2000, Ramirez, 2002; Haefele, 2003).

8.2.4 Bio-technical factors

The economic and environmental conditions that affect riculture are not constant (Petersen *et al.*, 2002). The stresses and uncertainty farmers face in accessing resources and demands for sustainable incomes and food resources demands th technical efficiency is improved. Neoclassical economic theory suggests that reduced risk and longer planning horizons should enhance expec ed returns and encourage investment (Gebremedhin and Swinton, 2003). If this is to be true for fish farming in he basin, production efficiency needs to be high, and its risk needs to be lowered.

The primary goal of rational pond management is to utilise existing conditions in ponds to produce fish economically. Polyculture utilises the concept of complementary eding habits and different ecological requirements to exploit resources. This results in improved yields, productivity and returns for similar eed and manure inputs. Experimental findings remain true, however only within the limits of the specified stocking densities, food supply and pond environmental ions (Sharma *et al.*, 1999).

In order to ensure that positive returns are obtained der different conditions to suit different resource constraints and production objectives, *O. niloticus* and/or *C. gariepinus* farming needs to be based on an understanding of the biology of species under local pond conditions. In polyculture, simulating stocking densities, stocking ratios and t e time as well as size at which the predator is stocked on the reproduction of *O. niloticus* would help improve technical efficiency. Stocking ratios and size at which the predator and pre should be introduced should be based on rates and leve s of fingerling recruitment rate, so as to target predation efficiency (Fischer and Grant, 994; Teichert-Coddington, 1996; Ludwig, 1996; de Graaf *et al*, 1996). Stocking densities and size at stocking affect production levels and influence the survival of fish (asser and Oswald, 2001, Hengsawat *et al.*, 1997). Stocking and harvesting recommendations should also be taken into account, in view of farmers' cash-flow constraints and demands of local consumer markets. Hence multi-staged stocking and harvesting would be worth considering. Species selection is important because it affects prod ction even with regard to the performance of the predator.

The study showed that if farmers were to adopt *C. gariepinus* either in polyculture or bait production, total input costs were likely to rise, as has previously been indicated. Given farmers' constraints in accessing resources, it is important to reduce risks of improved input use (Reardon *et al.*, 1997). Higher safety margins mean that farmers are less susceptible to yield-reducing factors (Haefele, 2003).

The findings of this study, when compared to experimen al results on *O. niloticus* production by NARO/MAAIF (2000[1]), show that the sub-optimal input use that currently characterises fish farming in the country has resulted in significant differences between farmers' actual and potential yields. However, given e constraints farmers face in accessing inputs, reducing this effect currently impli s improving the efficiency of use of available inputs. *C. gariepinus* in polyculture has demonstrated the ability to improve the efficiency of feed and manure utilisation in ponds.

However, even if farmers adopt polyculture, gaps are still likely to occur between actual and potential yields because, in practice, overcoming certain management constraints for farmers is difficult (Michielsens *et al.*, 2002). In addition, imperfect technologies and the difficulties inherent in managing complex culture syst ms may lead to substantial differences between actual performance and theoretical potential in any type of aquaculture system (Michielsens *et al.*, 2002). Rather than offering fish farmers fixed technological packages, it is therefore more useful to provide them with flexible production options, or to involve them in research for finalising the technologies, once 'almost-ready' technologies have been developed (Bentley *et al.*, 2004).

Bearing in mind that farmers' willingness to adopt a t chnology depends not only on their expectations for increased income or output, but also the alleviation of production constraints, the dynamics of resource accessibility sh also be integrated into management options (Doss, 2001). In the case of feed nd manure use for example, seasonal factors should be considered when developing uction recommendations. The competitive demand for both manure and labour for rop production is at a minimum during the dry season. It would be therefore be more ragmatic if management regimes were designed such that ponds were stocked in these months (time being particularly crucial for finding seed), and such that the crucial t for fertilisation also coincided with this time. Technically it may be feasible for both stocking and major fertilisation to take place in the same dry season, because studies in Thailand have shown that it is most economical to grow *O. niloticus* to 100-150 g for 3 months on fertiliser alone, before beginning supplementary feeding (Little *et al.*, 2004, Diana *et al.*, 1996, Green *et al.*, 2002). If stocking dates were correctly timed, the three month period of fertilisation could bring farmers to the onset of the rains when the availability of pasture and arable wastes on-farm is increased, and there is less competition from ivestock for food. Feeding can then be intensified, coinciding with the time when fish are older, and their nutritional requirements unlikely to be adequately met by fertilisation alone. In such a system, scarce feed inputs will have been optimised, as will scarce natural fertiliser, since the efficacy of fertilisation in still-ponds is known to be higher during the dry seasons because temperatures are higher, there is less cloud cover, and no rain to dilute pond water (Njoku, 1997; El-Sayed, 1996; Lin, 1997). The labour constraint in the rainy season meant that farmers invest far less time in pond management than they do in the dry season (see chapter 4). Stocking in the dry season would mean that the fish would already be larger when pond management standards dropp and survival rates would not be so critically affected. Further experimentation would be necessary to establish whether these kinds of management regimes can be successful for *C. gariepinus*. It is noteworthy that neither the current aquaculture research agenda nor current aquaculture extension advice have considered seasonality or tailoring manageme to meet such constraints. There are other ways of improving the efficiency of scarce fertiliser inputs, by changing the way in which they are applied (Azim *et al*., 2002[1]; Azim *et al*., 2002[2]). It was not within the scope of this thesis to research diff rent application methods for fertiliser or feed. However, it again needs to be stressed that a research agenda that was guided by an socio-economic understanding of fish-farmers, rather than only a technological understanding of fish farming, should begin to consider these ideas as priorities.

Despite these possibilities, the extent to which farme can increase food production using only low cost and locally available technologies and inputs needs to be realistically assessed (Pretty *et al.*, 2003). It is known that beyond extensive feed production, feed use and management become more critical to higher producti (Iinuma *et al.*, 1999). If technology in seed production for seed producers was more efficient and costs fell, farmers might find it profitable, and be better able t afford, more feed or even to top-up with artificial fertilisers. Costs can be lowered by argeting production to profitability indices, using locally prepared feed and vertically integrating hatchery and grow-out operations (Head *et al*., 1996). This is the kind of transformation which ha happened over the last decade in the poultry industry in Uganda Reduction in production costs and more efficient management are important for sustainable development, but the existence and capacity of support services is also necessary (Shang *et al*., 1998). A technology package on its own will not be enough for small-holder farmers, without services such as seed supply, cost-effective input supply, research and extension, financial services nd infrastructure for markets (Dorward *et al.*, 2004).

The sustainability of *C. gariepinus* production in the Lake Victoria Basin will ultimately depend on whether production and productivity make the application of inputs worthwhile for farmers (Ruben and van Ruijven, 2001). The greatest success for improvement in rural agriculture has been found where technological alternatives have optimised the use of scarce factors or have minimised he effects of factor scarcity. The outline of a plan for matching C gariepinus and *O. niloticus* polyculture with seasonal demands illustrates how this might work for aquaculture in Uganda. Developing these technologies further demands that research builds on e isting practice, and exploits farmers' participation and knowledge to complement scientific input (Alwang and Siegel, 1999; Fagerström *et al*., 2001; Chambers, 1989; Tacon, 2001; Allison and Ellis, 2001). This implies that researchers have to integrate socio-economic and environmental factors into the development of fish farming of indigenous spe , and have a more specific focus on farmer and location characteristics. The profiles established in this research for three agro-ecological zones were a first step in this direction.

8.3 Conclusions and recommendations

8.3.1 Overview

Under the prevailing conditions there is potential for *C. gariepinus* farming by fish farmers in the Lake Victoria Basin. The potential exi ts if *C. gariepinus* is farmed under polyculture for table fish or monoculture for bait, depending on the location and resources available to the farmer. Adding *C. gariepinus* to the existing fish farming systems can serve to intensify pond production with th limited available resources, therefore increasing pond returns and/or food output.

However, this potential can only be sustainably realised under the following conditions:

Local availability of seed is improved and seed costs re reduced.

Technical efficiency improves to minimise farmers' risks of production failure and loss.

Technologies are financially and ecologically viable, even for small-scale operations.

Based on the findings of the study, the following reco mendations can be made.

8.3.2 Recommendations to farmers

Opt for *O. niloticus-C. gariepinus* polyculture rather than *O. niloticus* monoculture, irrespective of feed or fertiliser constraints.

In view of the market preferences, farmers in the East of the country should focus on production of *C. gariepinus* as both bait and for table fish by optimising feeding regimes. Farmers in the West can use *C. gariepinus* for population control of tilapia, and can concentrate more on fertilising ponds for maximising tilapia yields.

In the event that only *O. niloticus* seed is available, and in conditions where feed and fertiliser for aquaculture are limited, a stocking den of 1 fish/m^2 would give a more marketable product and highest economic returns within realistic time period. It is not economically viable to begin *O. niloticus* monoculture if it is necessary to buy land or hire labour to construct a pond. It could only be economically viable if a pond is already available.

Current levels of production are unlikely to benefit large groups. Farming groups in the city would rather engage in other ventures, unless ponds are linked with additional enterprises, for example recreation or vegetable produ tion, in order to maximise returns.

Time invested in understanding production systems bett r in order to improve management will bring significant returns from improved pond profitability.

8.3.3 Recommendations for research and development

The current emphasis on *O. niloticus* monoculture does not reflect the economic realities of production under farmers' conditions, and emphasis should be switched to *O. niloticus -C. gariepinus* polyculture.

It is preferable to develop dual-purpose systems of *C. gariepinus* production for seed and bait, because of the constraints rural farmers are likely to face in accessing inputs, because of production and market risks. A dual purpose system reduces their risk exposure by enabling them to switch production easily, according to prevailing local demand.

Appropriate packages need to be developed for small and medium scale producers of seed. These packages can use low-cost inputs, rather than, for example, expensive imported tanks. Developing simple recommendations for improved transportation of seed, and mechanisms for disseminating these recommendations, is also a priority for the sector.

A new research agenda for aquaculture is needed. An integrated approach to research and analysis should be adopted, which starts with an u erstanding of farmers' local ecosystems and socio-economic asset constraints. Research needs to find wa to maximise efficiency of scarce resources.

Returns from aquaculture depend on the size and number of marketable fish. Therefore production research should focus on increasing these, nd be evaluated based on survival rates and proportion of marketable size in the yield rather than tonnes/unit area. Management recommendations to farmers should be given terms of the proportion (number of fish) of yield that will be of a particular size range (length and weight) and their corresponding respective prices, including estimated duration of production for different locations. This will make it possible for farmers to accurately gauge their options. Assessment of economic viability should be o both net and returns to various the limiting capitals farmers invest. For all product scenarios and local conditions optimum production cycles need to be determined, targe ing different production objectives and market requirements.

Extension information should include limitations of te under different situations and enterprise budgets.

Aquaculture has suffered from the same vicious circle policy level as in farmers' enterprises: poor performance of the sector resulted in poor investment in research and extension hence the continued poor performance of, and rest in, the sector. The study shows the sector has high potential, but structural pr at many levels means that more attention is required at many levels simultaneously – research, extension, seed and feed production, marketing and policy.

8.3.4 Recommendations for policy

Extension messages should focus at promoting *O. niloticus*-*C. gariepinus* polyculture rather than *O. niloticus* monoculture.

The capacity of the small- and medium private sector potential to produce seed i currently impaired by technical constraints. This is a critical area that needs to be looked into if local seed accessibility for farmers is to improve. Technical assistance would better be provided to such farmers through attachments over a longer period rather than the current one-two day training sessions they receive on-station. Site-specific constraints would be tackled in this way.

Bait supply to fishermen should be given serious thoug in view of the current productive status and economic value of the fisheries o the state. The current status quo is unsustainable. More sustainable options, such as through farming of *C. gariepinus,* should be sought. This would make it possible to stre ine policy and regulations on the harvesting of young fish. Currently, while it is inst regulations, market forces that have translated into foreign exchange are increasing p essure to harvest bait.

Current fish market studies are focussed on the export market. Information on local markets and demand is equally important as its availability determines the production techniques farmers are more likely to adopt and which research programs are appropriate. This is particularly important given the current agricultural policy framework of PMA. It is unlikely that there will be increased private sector investment in aquaculture, in particular in seed or feed production, unless the mark potential for aquaculture products is more clear, though informal indications are that lo al market potential is good. Although investment is supposed to come from private sector, there is a chicken and egg blockage – no seed, no farmers; no farmers no seed. Government an help break this vicious circle, perhaps using the non-profit sector in short term, before privatising it.

There is a need to encourage investment in inputs for aquaculture.

There is a need to involve farmers more in setting the research agenda, and in undertaking on-farm research.

The difficulties faced in undertaking this research, both in travelling to meet farmers and in conducting on-station experiments, indicates clearly the need to improve research capacity.

References

Adams, A.M., T. G. Evans, R. Mohammed, J. Farnsworth, 1997. Socio-economic Stratification by Wealth Ranking: Is it Valid? *World Development* 25, 1165-1172.

Adato M. and R. Meinzen-Dick, 2002. Assessing the Impact of Agricultural Research on Po erty Using the Sustainable Livelihoods Framework. Discussion Paper 128, Food Consumption and Nutrition Division, International Food Policy Research Institute, Washington D. C.

Aguilar-Manjarrez J. and S. S. Nath, 1998. A Strategic Reassessment of Fish Farming Potential in Africa. Committee for Inland Fisheries of Africa, (CIFA) Technical Paper No. 32, FAO, Rome.

Allison E.H. and F. Ellis, 2001. The Livelihoods Appr ch and Management of Small-Scale Fisheries. *Marine Policy* 25, 377-388.

Altieri M. A. and C. I. Nicholls, *unpublished*. The Third Way: Reaching Latin American Poor Farmers with Agroecological Approaches. Division of Insect Biology, Department of Environmental Science Policy and Management, University of California, Berkeley.

Alwang, J. and P. B. Siegel, 1999. Labour Shortages o Small Landholdings in Malawi: Implications for Policy Reforms. *World Development* 27, 146-1475.

Ashby J. A., 1986. Methodology for the Participation of Small Farmers in the Design of On-Farm Trials. *Agricultural Administration* 22, 1-19.

Association of Official Analytical Chemists (AOAC), 1990. Official Methods of Analysis, 15th Edn. Association of Official Analytical Chemists. Washington, D.C.

Athithan, S., T. Francis, N. Ramanathan and V. Ramadhas. 2 01. Cattle Urine as a Befitting Source of Nutrients for Carp Production. *Indian Journal of Fisheries* 48 (2), 231-235.

Azim M. E., M. A. Wahab, A. A. van Dam, M. C. M. Beveridge, E. A. Huisman and M. C. J. Verdegem, 2001. Optimization of Stocking Ratios of Two Indian Major Carps, Rohu *Labeo Rohita Ham*. and Catla *Catla Catla Ham*. In a Periphyton-Based Aquaculture System. *Aquaculture* 203, 33–49.

Azim M. E., M. C. J. Verdegem, M. M. Rahman, M. A. Wahab, A.A. van Dam and M.C.M. Beveridge , 2002[1]. Evaluation of Polyculture of Indian major carps in periphyton-based ponds. *Aquaculture* 213, 131–149.

Azim M.E., M. C. J. Verdegem, H. Khatoon, M. A. Wahab, A. A. van Dam and M. C. M. Beveridge, 2002[2]. A Comparison of Fertilization, Feeding and Three Periphyton Substrates for Increasing Fish Production in Freshwater Pond Aquaculture in Bangladesh. *Aquaculture* 212, 227–243.

Bahiigwa, G. B. A., 1999. Household Food Security in Uganda: An Empirical Analysis. unpublished , Economic Policy Research Centre, Kampala, Uganda.

Balarin, J. B. 1985. National Reviews for Aquaculture Development in Africa. 10. Uganda. FAO Fisheries Circular, No. 770.10.

Banerjee R. K., P. Ray, G. S. Sing, and B. R. Dutta, 1979; Poultry Droppings and Its Manurial Potentiality in Aquaculture. *Journal of the Inland Fisheries Society* 2, 94-108

Barg U. and M. J. Phillips, 1997. Selected Developments and Trends. Environment and Sustainability. In: Review of the State of World Aquaculture. FAO Fisheries Circular No. 886 FIRI/C886 (Rev. 1), Rome, Italy. Online: http://www.fao.org/docrep/003/w7499e/w 9e14.htm

Barnett V., 2002. Sample Survey: Principles and Methods. 3rd Edn. Arnold, UK.

Bebbington A., 1999. Capitals and Capabilities: A Framework for Analysing Peasant Viability, Rural Livelihoods and Poverty. *World Development* 27, 2021-2044.

Bentley, J., G. Thiele, R. Oros, C. Velasco, 2004. Cinderella's Slipper: Sondeo Surveys and Technology Fairs for Gauging Demand. AgREN, Network Paper 138. ODI, UK.

Berdegué J. A. and G. Escobar, 2002. Rural Diversity, Agricult ral Innovation Policies and Poverty Reduction. AgREN, Network paper 122, ODI, UK.

Beveridge, M. C. M., M. J. Phillips and D. J. Macintosh. 1997. Aquaculture and the Environment: The Supply of and Demand for Environmental Goods and Services by Asian Aquaculture and the Implications for Sustainability. *Aquaculture Research* 28, 797-807.

Boehringer A. and E. T. Ayuk, 2003. Farmer Nurseries s a Catalyst for Developing sustainable Land Use Systems in Southern Africa. Part B: support Systems, Early Impact and Policy Issues. *Agricultural Systems* 77, 203-217.

Bonnard P., 1999. Increasing the Nutritional Impacts of Agricultural Interventions. Paper presented at the Greater Horn of Africa Regional Workshop: Agricultural Policy, Resource Access and Human Nutrition, Addis Ababa, Ethiopia. November, 1999 for F nd Nutritional Technical Assistance Project, Academy of Educational Development, USA.

Boyd C. E. and J. E. Bowman, 1997. Pond Bottom Soils. In: Egna, H. S. and C. E. Boyd, (Eds.) Dynamics of Pond Aquaculture, pp. 135-244. CRC Press, New York.

Brummett R. E., 1994. How Can Research Best Serve the Needs of Aquaculture in Sub-Saharan Africa?. *NAGA*, *The ICLARM Quarterly*, 17(4), 15-17.

Brummett, R. E. 1996. Species selection for smallholder aquaculture NAGA. *The ICLARM Quarterly* 19 (4), 19-22. Contribution No 1339.

Brummett R. E., 1999. A Farmer-Participatory Approach to Aquaculture Research and Technology Development and Dissemination. Paper Presented at the FAO Aquaculture Develo ment Study Group Workshop, Accra, Ghana.

Brummett, R.E. 2000. Indigenous Species for African Aquaculture Development. Paper presented to the World Aquaculture Society Annual Meeting, 1-5 May, Nice, France. Online: www.oceansatlas.com/world_fisheries_and_aquaculture/html/resources/aqua/introspec/exoticspecies.htm

Brummett R. E. and R. P. Noble, 1995. Farmer-Scientist Research Partnerships and Smallholder Integr ted Aquaculture in Malawi. In Seminar: The Management of Integrated Freshwater Agro-Piscicultural Ecosystems in Tropical Areas, pp 443-464. Eds. J. J. Symoens and J. C. Micha. Technical Centre for Agricultural and Rural Co-operation (CTA). Royal Academy of Overseas Sciences, B ussels.

Brummett R. E. and M. J. Williams, 2000. The Evolution of Aquaculture in African Rural and Economic Development. *Ecological Economics* 33, 193-203.

Cacho O. J., 1993. Development and Implementation of Fish-Farm Bio-economic Model: A Three-Stage Approach. In: Models and Economics. Eds. Hatch U. and H. Kinnuc n pp 55-72. Westview Press Inc. USA. 288pp.

Cacho, O. J., 1997. Systems Modelling and Bioeconomic Modelling in Aquaculture. *Aquaculture Economics and Management*, 1(1), 45-64.

Carney, D., 1998. Sustainable Rural Livelihoods: What Contribution Can We Make? DFID, London. (Papers presented at International Development Advisers' Conference July 1998).

Chambers, R., 1989. Introduction. In: Chambers R., R., A. Pacey and L. A. Thrupp (Eds). Farmer Innovation and Agricultural Research. pp 1-3. Intermediate Technology Publications, UK.

Chatfield C., 1995. Problems Solving. A Statistician's Guide. Second Edition. Chapman & Hall, UK.

Chellappa S., 1996. The Diet of Hybrid Red Tilapia *Oreochromis niloticus* (L.) x *Oreochromis mossambicus* (Peters) Reared in the Freshwater Ponds of North-Eastern Brazil. *Aquaculture Research* 27, 945-952.

Chikafumbwa, F. J. K., 1996. The Use Of Napier Grass (*Pennisetum purpureum*) And Maize (*Zea mays*) Bran As Low Cost Tilapia Aquaculture Inputs. *Aquaculture* 146, 101-107

Chikafumbwa, F. J. K., A. Costa-Pierce, D. M. Jamu and W. K. Kadongola. 1993. Investigations on the Use of On-Farm Resources as Pond Inputs for the Culture of *Tilapia rendali a*nd *Oreochromis shiranus o*n Small Holder Farms In Rural Malawi. *Aquaculture* 117, 261-271.

Chopak C. J. and J. R. Newman, 1998. The Status and P ntial of Michigan Aquaculture. Michigan State University Extension. Ag. Experiment Station Special orts-SR509201. Online: http://web1.msue.msu.edu/imp/modsr/sr509201.html

Clarke G.M., 1994 Statistics and Experimental Design. An Introduction for Biologists and Biochemists. John Wiley & Sons Inc., New York:

COMPETE and Gowa, 2001. The Path Forward in Uganda's Coffee Sector. Prepar for the Presidential Conference on Export Competitiveness, February. 2001. Ministry of Finance Planning and Economic Development, Kampala, Uganda.

Cuenco, M. L., 1989. Aquaculture Systems Modelling: An Intro tion with Emphasis on Warm Water Aquaculture. ICLARM Studies and Reviews 19, 46pp. International Centre for Living Aquatic Resources Management, Manila, Phillipines.

Deininger, K., and J. Okidi, 2002. Capital Market Access, Factor Demand, and Agricultural Development in Rural Areas of Developing Countries: the Case of Uganda. World Bank Economic and Policy Research Centre. http://www.eldis.org/fulltext/EPRC_Okidi3.pdf

Diana J. S.,1997. Feeding Strategies. In: Egna, H.S. and C. E. Boyd C.E., (eds.) Dynamics of Pond Aquaculture, pp. 245-262. CRC Press, New York. 437 pp.

Diana, J. S., D. D. Dettweiler, and C.K. Lin, 1991a. Effect of Nile Tilapia (*Oreochromis niloticus*) On The Ecosystem Of Aquaculture Ponds, and its Significance to the Trophic Cascade Hypothesis. *Canadian Journal of Fisheries and Aquatic Sciences* 48,183-190.

Diana, J. S., C. K. Lin, and K. Jaiyen, 1994. Supplemental Feeding Of Tilapia In Fertilized Ponds. *Journal of the World Aquaculture Society* 25, 497-506.

Diana, J.S., C. K. Lin, and P.J. Schneeberger, 1991b. Relationships Among Nutrient Inputs, Water Nutrient Concentrations, Primary Production, and Yield of *Oreochromis niloticus* in ponds. *Journal of the World Aquaculture Society* 92, 323-341.

Diana, J. S., C. K. Lin, and Y. Yi, 1995. Stocking Density and Supplemental Feeding. In: H. Egna, B. Goetze, D. Burke, M. McNamara, and D. Clair, (Editors), Thirteenth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, OR, USA, pp. 117-125.

Diana, J. S., C. K. Lin, and Y. Yi, 1996. Timing of Supplemental Feeding for Tilapia Production. *Journal of the World Aquaculture Society* 27(4), 410-419.

Diana J. S., J. P. Szyper, T. Batterson, C. Boyd and R. Piedrahita (1997) Water Quality in Ponds. In: Egna, H.S.and C. E. Boyd (Eds.) Dynamics of Pond Aquaculture, pp. 53-72. CRC Press, New York. 437 pp.

Dorward, A. S. Anderson, S. Clark, B. Keane and J. Moguel , 2001. Asset Functions and Livelihood Strategies: A Framework for Pro-Poor Analysis, Policy and Practice. Contributed paper to EAAE seminar on Livelihoods and Rural Poverty, September 2001. European Association of Agricultural Economists, The Hague. Online: http://www.wye.imperial.ac.uk/AgEcon/ADU/CDPR/index.html

Dorward, A., S. Fan, J. Kydd, H. Lofgren, J. Morrison, C. Poulton, N. Rao, L. Smith, H. Tchale, S. Thorat and P. Wobst, 2004. Rethinking Agricultural Policies for Pro-poor Growth. *Natural Resource Perspectives*, No. 94. ODI, London.

Doss C. R., 2001. Designing Agricultural Technology for Women Farmers: Lessons from 25 Years of Experience. *World Development* 29, 2075-2092.

Duan D., 1998. Fish Farming Integrated with Livestock and Poultry in China. In: Mathias, J.A., A. T. Charles and H. W. Baoteng, (Eds.) Integrated Fish Farming, pp. 73-82. CRC Press, New York.

The East African, 2002. Lake Victoria Basin: So Rich Yet So Poor. Features. Jan 14th, 2002., The Nation Group, Nairobi, Kenya.

Edwards P., 1998. A Systems Approach for the Promotion of Integrated Aquaculture. *Aquaculture Economics and Management* 2(1), 1-12.

El-Sayed A. F.M., 1996. Effects of Pond Depth and Water Temperature on the Growth, Mortality and Body Composition of Nile Tilapia, *Oreochromis niloticus* (L.). *Aquaculture Research* 27, 681-687.

Ellis F. and G. Bahiigwa, 2003. Livelihoods and Rural Poverty Reduction in Uganda. *World Development* 31, 997-1013.

Engel P.G.H., 1995. Facilitating Innovation. An Action-Oriented Approach and Participatory Methodology to Improve Innovative Social Practice in Agriculture. Ph.D. Thesis. Wageningen Agricultural University, The Netherlands.

Fagbenro O. A. and D. H. J. Syndenham, 1988. Evaluation of *Clarias isheriensis* (Sydenham) under semi-intensive management in ponds. *Aquaculture* 74, 287-291

Fagerstrom H. H., M. van Noordwijk. T. Phien and N. C. Vinh, 2001. Innovations within Upland Rice-Based Systems in Northern Vietnam with *Tephrosia candida* as Fallow Species, Hedgerow, or Mulch: Net Returns and Farmers' Response. *Agriculture, Ecosystems and Environment*, 86(1), 23-37.

Fischer G. W and W. E. Grant, 1994. Use of a Native Predator to Control Overcrowding in Warm-Water Polyculture Ponds: Simulation of a Tucunare (*Cichla monculus*) - Tilapia (*Oreochromis niloticus*) system. *Ecological Modelling* 72, 205-227.

Garg, S. K. and A. Bhartnagar, 2000. Effect of Fertilisation Frequency on Pond Productivity and Fish Biomass in Still Water Ponds Stocked with *Cirrhinus mrigala* (Ham.). *Aquaculture Research* 31, 409-414.

Gebremedhin, B.and S. M. Swinton, 2003. Investment in soil Conservation in Northern Ethiopia: The Role of Land Tenure Security and Public Programs. *Agricultural Economics* 29, 69-84.

Gladwin C., J. S. Peterson and A. C. Mwale, 2002. The Quality of Science in Participatory Research: A Case Study from Eastern Zambia. *World Development* 30, 523-543.

Glasser F. and M. Oswald, 2001. High Stocking Densities Reduce *Oreochromis niloticus* Yield: Model Building to Aid the Optimisation of Production. *Aquatic Living Resources* 14, 319-326.

Göhl, B. 1981. Tropical feeds. FAO, Rome

Goldman I., M. Harrison, J. Carnegie and B. Ddungu 2001. Exploring Livelihoods and Identifying opportunities and Services for Livelihood Enhancement Through Forestry. Synthesis report from nine District surveys. Forestry Secretariat, Government of Uganda, Kampala.

Goletti F., 1999. Agricultural Diversification and Rural Industrialisation as a Strategy for Rural Income Growth and Poverty Reduction in Indochina and Myanmar. Paper he Symposium on 'Food Policy in Indochina and Myanmar: The Effects of Globalisation' by International Food Policy Research Institute and the Ministry of Agriculture and Rural Development, Hanoi.

Gomiero T., M. Giampietro, S. G. F. Bukkens, M. G. Paoletti 1997. Biodiversity use and Technical Performance of Freshwater Fish Aquaculture in different Socioeconomic Contexts: China and Italy. *Agriculture, Ecosystems and Environment* 62, 169-185.

Goudswaard, P. C. and F. Witte, 1997. The catfish fauna of Lake Victoria after the Nile perch upsurge. *Environmental Fish Biology* 49(1), 21-43.

Goudswaard P. C., F. Witte, E. F. B. Katunzi, 2002. The Tilapiine Fish Stock of Lake Victoria before and after the Nile Perch upsurge. *Journal of Fish Biology* 60, 838-856.

de Graaf, G., F. Galemoni, and B. Banzoussi, 1996. Recruitment Control of Nile Tilapia, *Oreochromis* *niloticus*, by the African Catfish, *Clarias gariepinus* (Burchell 1822), and the African Snakehead, *Ophicephalus obscuris*. I. A Biological Analysis. *Aquaculture* 146, 85-100.

Green, B. W., Z. El Nagby and H. Hebicha, 2002. Evaluation of Nile Tilapia Pond Management Strategies in Egypt. *Aquaculture Research* 33, 1037-1048.

Gupta A., M. Biswanth and L. Uttam, 1985. Productive Potentiality and Economic Viability of Poultry manure Alone and in Combination with Pig Dung in Carp Culture. *Journal of the Inland Fisheries Society* 20:3

Gwatkin D. R. and M. Guillot, 2000. The Burden of Disease among the Global Poor: Current Situation, Future Trends, and Implications for Strategy. World Bank, Washington DC.

Gwatkin D. R., S. Rustein, K. Johnson, R. Pande and A. Wagstaff, 2001. Socio-Economic Differences in Health, Nutrition and Population in Uganda. HNP/Povert Thematic Group of The World Bank.

Haefele, S. M., 2003. A Framework to Improve Fertilis Recommendations for Irrigated Rice in West Africa. *Agricultural Systems* 76, 313-335.

Hair J. Jr., R. E. Anderson, R. L. Tatham, and W. C. Black, 1998. *Multivariate Data Analysis*, Prentice-Hall, Inc., USA.

Harrison P., 1987. The Greening of Africa: Breaking T ugh in the Battle for Land and Food. International Institute for Environment and Development – Earthscan. Paladin Grafton Books, UK.

Harrison E., 1994. Aquaculture in Africa: Socio-Economic Dimensions. In: Muir F. J. and R. J. Roberts (Eds). Recent Advances in Aquaculture V, pp. 240-229. Groom Helm, London.

Harrison M., R. Ssabaganzi, I. Goldman and J. Carnegie 2004. Reform of the Forestry Advisory Service: Learning from Practice in Uganda. Natural Resource Perspectives 93. ODI, London

Hau, A. and M. Von Oppen, 2002. Market Access and Agricultural Productivity in Doi Inthanon Villag s. International Symposium Sustaining Food Security and Managing Natural Resources in Southeast Asia -Challenges for the 21st Century- January 8-11. 2002 at Chiang Mai, Thailand.

Haylor G. and S. Bland, 2001. Integrating Aquaculture into rural Developme n Coastal and Inland Areas. In: Subasinghe R. P. P. Bueno, M. J. Phillips, C. Hough, S. E. McGladdery & J. R. Arthur., (eds.) Aquaculture in the Third Millennium. Technical Procee s of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 7381. NACA, Bangkok and FAO, Rome.

Hazell P., 1998. Equity and Environmental "Modifiers" for rural Development Policies. In: Agriculture and the Environment. Perspectives on Sustainable Rural Development. Eds. Lutz E., H. P. Binswanger, P. Hazell and A. McCalla. The World Bank, Washington DC

Head W. D., A. Zerbi and W. O. Watanabe, 1996. Economic Evaluation of Commercial-Scale, Saltwater Pond Production of Florida Red Tilapia in Puerto Rico. *Journal of the World Aquaculture Society* 27, 275-289. (Abstract)

Hecht, T., 2000. Considerations on African Aquaculture. *World Aquaculture* 31(1), 12-15.

Hengsawat K., F. J. Ward and P. Jaruratjamorn, 1997. The Effect of Stocking Density on Yield, Growth and Mortality of African Catfish (*Clarias gariepinus* Burchell 1822) Cultured in Cages. *Aquaculture* 152, 67-76.

Herrero M., R. H. Fawcett and J. B. Dent 1999. Bio-economic Evaluation of Dairy Farm Management Scenarios using Integrated Simulation and Multiple-Criteria Models. *Agricultural Systems* 62, 169-188.

Hishamunda N., C. M. Jolly, R. Engle and R. Carole, 1998. Evaluating and Managing Risk in Small-Scale Fish Farming in a Developing Economy: An Application to Rwanda. *Aquaculture Economics and Management* 2, 31-39.

Hoekstra D. A., 1994. Factors Influencing the Economic Viability f Three Agroforestry Systems in Eastern and Southern Africa. *Forest Ecology and Management* 64, 265-276. (Abstract)

Iinuma, M., K. R. Sharma, P. Leung, 1999. Technical Efficiency of Carp Pond Culture in P ninsula Malaysia: An application of Stochastic Production Frontier and T al Inefficiency Model. *Aquaculture* 175, 199-213.

Isyagi, A. N., 2001 Aquaculture in Uganda. In: Agriculture in Uganda, Volume 4: Livestock and Fisheries. Chapter 13, pp 341-363. NARO. Fountain Publishers, Kampala. 380pp.

Jamu, D. M. and R. H. Piedrahita, 2002. An organic matter and nitrogen dynamics model for the ecological analysis of integrated aquaculture/agriculture systems: I. Model development and calibration. *Environmental Modelling & Software* 17, 571-582.

Jansen E. J., 2003. Socio-Economics of the Nile Perch Fishery on Lake Victoria. h Fisheries - Poor Fisher folk. Some Preliminary Observations About the Effects of Trade and Aid in the Lake Victoria Fisheries. Online: http://www.iucn.org/places/earo/pubs/wetlands/ ICHPOOR.PDF

Jauncey K., 2000. Nutritional Requirements. In: Beveridge M. C. M. and B.J. McAndrew, (Eds.) Tilapias: Biology and Exploitation, pp. 327-376. Kluwer Academic Publishers, The Netherlands. 505pp.

Jolly, C. M. and H. A. Clonts, 1993. Economics of Aquaculture. The Howar ss, USA.

Kaelin and Cowx, 2002. Outline of the Path Forward In Uganda's Fisheries Sector. Online: http://www.foodnet.cgiar.org/market/Uganda/Reports/Fis .pdf

Kajjansi Aquaculture Research and Development Centre (KARDC), 2000. Aquaculture in Uganda. Results for the Baseline Survey, 1999- 2000. National Agricultural Research Organisation (NARO) and Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Uganda.

King A., 2002. Case Study: Livestock, Hides, Skins and Leather Products. Uganda. European Union. Online: http://www.foodnet.cgiar.org/market/Uganda/Reports/liv stocknnexes.pdf

Knud-Hansen C.F., 1997. Experimental Design and Analysis in Aquaculture. In: Egna, H. S. and C. E. Boyd, (eds.) Dynamics of Pond Aquaculture, pp. 325-376. CRC Press LLC, New York.

Kudhongania, A. W. and D. B. R Chitamwebwa, 1995. Impact of environmental change, species introductions and ecological interactions on the fish stocks of Lake Victoria. In Pitcher, T. J. and P. J. B Hart, (eds.) The Impact of Species Changes in African Lakes pp. 19-32. Fish and Fisheries Series 18, Chapman & Hall, London, UK.

Lem and Shehadeh,1997. ch 2.7 international trade in quaculture products,1997 International Trade in Aquaculture Products, in FAO Inland Water Resources and Aquaculture Service, Fishery Resources Division Review of the state of world aquaculture. FAO Fisheries Circular. No. 886, Rev.1. FAO, Rome.

Leveque C., 1997. Biodiversity Dynamics and Conservat The Freshwater Fish of Tropical Africa. Cambridge University Pres. ORSTOM

Lin C. K., Y. Yi, L.T. Luu and J. S. Diana, 2003. Asse ing Watershed Ponds for Aquaculture Development in Thai Nguyen, Vietnam. GIS Planning, Policy and Global Data Analysis Research 2 (10GISR2)/Study/Thailand and Vietnam. Pond Dynamics/Aquaculture Collaborative Research Support Program. Online: http://www.aqua.ait.ac.th/modules/library/singlefile.php?cid=1&lid=31

Lightfoot C., J. P. Dalsgaad and M. A. Bimbao, 1993. Farmer Participatory Procedure for Managing and Monitoring Sustainable Farming Systems. *Journal of Asian Farming System Assoc.*, 2:67-87

Lightfoot C., M. Prein and T. Lopez, 1994. Bioresource Flow Modelling with Farmers. ILEIA Newsletter, October Issue, 22-23.

Lin C K, D. R. Teichert-Coddington, B. W. Green and K. L. Veverica, 1997 Fertilization regimes. In: H.S. Egna and K.L. Boyd (Editors), Dynamic of pond aquaculture. CRC Press, New York. 437 pp.

Little, D.C. and P. Edwards, 2004. Impact of nutrition and season on pond culture performance of mono-sex and mixed-sex Nile tilapia (*Oreochromis niloticus*). *Aquaculture* 232, 279-292.

Little D. C., P. Surintaraseree, N. Innes-Taylor, 1996. Fish Culture in Rainfed Rice Fields of North East

Thailand. *Aquaculture* 140, 295-321.

Ludwig G. M., 1996. Comparison of Channel Catfish, *Ictalurus punctatus*, and Fathead Minnow, *Pimephales promelas,* Production and Water Quality among a Polyculture and Two Monoculture Systems. *Aquaculture* 144, 177-187.

Machena C. and J. Moehl, 2001. African Aquaculture: A Regional Summary with Emphasis on Sub-Saharan Africa. In: Subasinghe R. P. , P. Bueno, M. J. Phillips, C. Hough, S. E. McGladdery and J. R. Arthur , (eds.) Aquaculture in the Third Millennium. Technical Proce dings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. NACA, Bangkok and FAO, Rome.

Maina J. G., R. M. Beames, D. Higgs, P. Mbugua, G. Iwama and S. Kisia, 2002. Digestibility and Feeding Value of some Feed Ingredients Fed to Tilapia *Oreochromis niloticus* (L.). *Aquaculture Research* 33, 853-862.

McMillan, M. S., and W. Masters. 2003. An African growth trap: Production technology and the time-consistency of agricultural taxation, R&D and investment. *Review of Development Economics* 7, 179-191.

Michielsens, C. G. J., K. Lorenzen, M. J. Phillips and R. Gauthier, 2002. Asian carp farming systems: Towards a typology and increased resource use efficiency. *Aquaculture Research* 33 (6), 403-413.

Milstein, A. 1993. Factor and Canonical Correlation Analyses: Basic concepts, Data Requirements and Recommended Procedures. p24-31. In: Prien M. G Hulata and D. Pauly , (Eds.) Multivariate Methods in Aquaculture Research: Case Studies of Tilapias in Experimental and Commercial Systems. ICLARM Study Review 20, 221pp. Philippines.

Milstein, A., A. Goldman, and G. Hulata. 1993. Multiple Regression Analysis Of Fish Yield And Profit In Commercial Fish Farms In Israel. pp161-177. In: M. Prein, G. Hulata and D. Pauly (eds.). Multivariate Methods In Aquaculture Research: Case Studies Of Tilap s In Experimental And Commercial Systems. ICLARM Studies and Reviews 20, 221pp. Philippines.

Milstein A. and G. Hulata 1993. Factor Analysis and Canonical Correlation Analysis of Fish Production in Commercial Farms in Israel. pp 119-160. In: M. Prien , G Hulata and D. Pauly., (Eds.) Multivariate Methods in Aquaculture Research: Case Studies of Tilapias in Experimental and Commercial Systems. ICLARM Study Review 20, 221pp. Philippines.

Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), 1999. *Fishery Statistics.* Fisheries Resources Department, Ministry of Agriculture, Animal Industry and Fisheries, Kampala, Uganda.

Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), 2000. *Report on Uganda Fisheries Frame Survey, Vol II. Report Summary of Landing Facilities, Fishing Crafts and Gears.* Statistical Unit, Fisheries Resources Department. Ministry of Agriculture, Animal Industry and isheries, Kampala.

Ministry of Agriculture, Animal Industry and Fisheries and Ministry of Finance, Planning and Economic Development (MAAIF/MFPED), 2000. *Plan for the Modernisation of Agriculture. Eradicating Poverty in Uganda*. Government Strategy and Operational Framework. Ministry of Agriculture, Animal Industry and Fisheries, Kampala, Uganda.

Ministry of Finance, Planning and Economic Development (MFPED), 2000[1]. *Poverty Eradication Action Plan*. Kampala: Ministry of Finance, Planning and Economic Development, Kampala, Uganda.

Ministry of Finance, Planning and Economic Development (MFPED), 2000[2]. *Learning from the Poor. Uganda Participatory Poverty Assessment Report*. Kampala: Ministry of Finance, Planning and Economic Development , Kampala, Uganda.

Ministry of Finance, Planning and Economic Development (MFPED), 2001. *Uganda Poverty Status Report. Milestones in the Quest for Poverty Eradication*. Ministry of Finance, Planning and Economic Development, Kampala, Uganda.

Ministry of Finance, Planning and Economic Development (MFPED), 2002[1]. *Summary of Background to the Budget 2001/02.* Ministry of Finance, Planning and Economic Development , Kampala, Uganda.

Ministry of Finance, Planning and Economic Development (MFPED), 2002[2]. *Uganda Poverty Reduction Strategy Paper. Progress Report 2002*. Ministry of Finance, Planning and Economic Development , Kampala, Uganda.

Ministry of Finance, Planning and Economic Development (MFPED), 2003[1]. *Summary of Background to the Budget 2002/03*. Ministry of Finance, Planning and Economic Development , Kampala, Uganda.

Ministry of Finance, Planning and Economic Development (MFPED), 2003[2]. *Uganda Poverty Status Report, 2003. Achievements and Pointers for the PAEP Revision*. Ministry of Finance, Planning and Economic Development , Kampala, Uganda.

Ministry of Finance, Planning and Economic Development (MFPED), 2004. *Background To The Budget For Financial Year 2004/05*. Ministry of Finance, Planning and Economic Development , Kampala, Uganda.

Moav R., G. Wohlfarth, G. Schroeder, G. Hulata, 1977. sive Polyculture of Fish in Freshwater ponds. I. Substitution of expensive feeds by liquid cow manure. *Aquaculture* 10, 25-43

Mugabe, J. 2003. Biodiversity and sustainable development in Africa in J. Mugabe, and N. Clark, (Eds.), Managing Biodiversity. Nairobi, Kenya: African Centre for Technology Studies

Muir J. F and J. A. Young, 1998. Strategic Issues in w Species Development for Aquaculture. Paper: XXXIII International Symposium on New Species for Mediterranean Aquaculture. Alghero, April, 1998.

Mutumba-Lule, J., 1999. Confusion Over Fish Ban as City Council, Uganda Government Differ. In: The East African, May 5-12, 1999. Online: http://nationaudio.com/News?EastAfrican/030599/Regional/Regional14.html

Naegel L. C. A., 1995. Research with a Farming System Perspective needed for the Development of Small-Scale Aquaculture in Non-Industrialised Countries. *Aquaculture International* 3, 227-291

Nanyenya W. , P. K. Ngategize, M. Kyangwa, and L. Aliguma, 1999. An Assessment of Technology Adoption, Profitability and Competitiveness of Aquaculture in Ug nda. Socio-Economics Programme. National Agricultural Research Organisation (NARO), Uganda.

NARO/MAAIF Fish Farming Project, 2000[1]. On Farm Trials Programs 2000 (Preliminary Results) National Agricultural Research Organisation (NARO) and Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Uganda.

NARO/MAAIF Fish Farming Project, 2000[2], Baseline Survey. Regional Data Tables. Uganda: National Agricultural Research Organisation (NARO) and Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Uganda.

Nath S. S., J. P. Bolte and D. H. Ernst, 1995. Decision Support for Pond Aquaculture, Planning and Management. Paper presented at the Sustainable Aquaculture Conference held by PACON International, Hawai, 1995.

National Environment Management Authority (NEMA), 1999. State of the Environment Report for Uganda, 1998, National Environment Management Authority, Kampala, Uganda.

National Environment Management Authority (NEMA), 2001. State of Environment Report for Uganda 2000/2001, National Environment Management Authority, Kampala, Uganda.

Njoku D.C., 1997. Effects of Different Manure Levels on Fish Growth, Mortality and Yield in a Horizontally-Integrated Fish-Cum-Poultry Farming System in Nigeria. *Aquaculture Research* 28, 651-660.

NRI and IITA, 2002. Transaction Costs Analysis For Uga dan Crops. Final report for PMA. NRI/IITA

Ntiba M., 2003. Capacity Development in the Lake Victoria Basin, East frica. 14. MSW conference. 2003.

Nyamutale, *pers comm*. Organisation of Agricultural Services in Kampala Di ct. District Fisheries Officer, Kampala District.

Ogutu-Ohwayo R., 1990. The Decline of Native Fishes of Lakes Victoria and Kyoga (East Africa) and the Impact of Introduced Species, Especially the Nile Perch, *Lates niloticus*, and the Nile Tilapia, *Oreochromis niloticus*. *Environmental Biology of Fishes* 27, 81-96.

Okidi J. A. and G. K. Mugambe, 2002. An Overview of Chronic Poverty and Development Policy in Uganda. EPRC Working Paper 11. Economic Policy Research Centre Kampala, Uganda.

Orach-Meza F. L., 2000. The Rationale for the Lake Victoria Environment Management Project. LVEMP News Bulletin 1(1), 2.

Orr A. and B. Mwale (2001) Adapting to Adjustment: Smallholder Livelihood Strategies in Southern Malawi. *World Development* 29, 1325-1343.

d'Oultremont, T. and A. Gutierrez. 2002. A multitrophic model of a rice-fish agroecosystem: II. Linking the flooded rice-fishpond system. *Ecological Modelling* 155, 159-176.

Owori-Wadunde A., 2001. Historical Perspectives of Aquacult evelopment in Uganda. Paper Presented at the National Aquaculture Information Workshop, Kampala, 15-16 February, 2001.

Panayotou T., S. Wattanutchariya, S. Isvilanonda and R. Tokrisna 1982. The Economics of Catfish Farming in Central Thailand. ICLARM Technical Reports 4, 60 pp. Kasetsart University and Development Institute, Bangkok, Thailand and International Centre for Living Aquatic Resources Management (ICLARM), Philippines

Pannell D. J., 1997. Sensitivity Analysis of Normative Economic M dels: Theoretical Framework and Practical Strategies. *Agricultural Economics* 16, 139-152.

Pauly D., M. Prein and K. D. Hopkins, 1993. Multiple Regression analysis of Aqua lture Experiments Based on the 'Extended Gulland-and Holt Plot': Model Derivation, Data Requirements and Recommended Procedures pp.13-23. In: M. Prein, G. Hulata and D. Pauly (eds). Multiv ate Mehtods in Aquaculture Research: Case Studies of Tilapias in Experimental and Commercial systems. ICLARM Stud Rev 20, 221 pp.

Pedini M., 1997. Regional Reviews: Sub-Saharan Africa. In: Review of the State of World Aquaculture. FAO Fisheries Circular No. 886 FIRI/C886(Rev.1) Italy www.fao./org/docrep

Petersen E. H., D. Pannell, T. L. Nordblom and F. Shomo, 2002. Potential Benefits from Alternative Areas of Agricultural Research for Dryland Farming in Northern Syria. *Agricultural Systems* 72, 93-108.

Phillips M.J., C. Boyd and P. Edwards, 2001. Systems Appro ch to Aquaculture Management. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Co ence on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. Pp.63-72. NACA, Bangkok and FAO, Rome

Pido M. D., 1995. The Application of Rapid Rural Appraisal Te hniques in Coastal Resources Planning: Experience in Malmpaya Sound, Philippines. *Ocean & Coastal Management* 26, 57-72.

Prein, M. 2002. Integration of Aquaculture into crop-animal systems in Asia. *Agricultural Systems* 71, 127-146.

Pretty J. N., J. Morison and R. Hine, 2003. Reducing Food Poverty by Increasing Agricultur l Sustainability in Developing Countries. *Agriculture, Ecosystems and Environment* 95, 217-234.

Rahman M. A., 1998. Polyculture of Carps in Integrated Broiler-Cum-Fish Farming Systems. In: Mathias, J.A., A. T. Charles and H. Baoteng, (Eds.) Integrated Fish Farming, pp. 83-96. CRC Press, New York.

Ramirez, R., 2002., The Effectiveness of Small-Scale Agriculture Interventions on Household Food Security: A Review of the Literature (Phase 1, Part 2). The Canadian Foodgrains Bank.

Rana, K., 1997 Recent Trends in Global Aquaculture Production: 1984-1995, in FAO Aquaculture Newsletter (FAN) - No. 16, August 1997. FAO, Rome

Reardon T., V. Kelly, E. Crawford, B. Diagana, J. Dione, K. Savado o and D. Boughton 1997. Promoting sustainable Intensification and Productivity Growth in Sahel Agriculture after Macroeconomic Po icy Reform. *Food Policy* 22 , 317-327.

Riley J. and C. J. Alexander, 1997. Statistical Literature for Participatory On-Farm Research. *Experimental*

Agriculture 33, 73-82.

Rojas, U. J. B. and J. A. J. Verreth, 2003. Growth of *Oreochromis aureus* Fed with Diets Containing Graded Levels of Coffee Pulp and Reared in Two Culture Systems. *Aquaculture* 217, 275-283.

Ross L. G., 2000. Environmental Physiology and Energetics. In: Beveridge, M. C. M. and B. J. McAndrew, (eds.) Tilapias: Biology and Exploitation, pp. 89-128. Kluwer Academic Publishers, The Netherlands. 505pp.

Ruben R. and A. van Ruijven, 2001. Technical Coeffici nts for Bio-Economic Farm Household Models: A Meta-Modelling approach with Applications for Southern Mali. *Ecological Economics* 36, 427-441.

Scheren P. A. G. M., H. A. Zanting and A. M. Lemmens, 2000. Estimation of Water Pollution Sources in Lake Victoria, East Africa: Application and Elaboration of the Rapid Assessment Methodology. *Journal of Environmental Management* 58, 235-248.

Setboonsarng, S. and P. Edwards, 1998. An Assessment of Alternative Strategies for the Integration of Pond Aquaculture into the Small-Scale Farming System of North-East Thailand. *Aquaculture Economics and Management* 2, 151-162.

Serruya, C., and U. Pollingher, 1983. Lakes of arm Belt. Cambridge University Press, New York.

Shang Y. C., 1990. Aquaculture Economic Analysis: Volume 2. The World Aquaculture Society, USA. 211 pp.

Shang Y. C., PingSun Leung and Bith-Hong Ling, 1998. Comparative Economics of Shrimp Farming in Asia. *Aquaculture* 164, 183-200.

Sharma K. R., PingSun Leung, H. Chen, 1999. Economic Efficiency and Optimum Stocking Densities in Fish Polyculture: an Application of Data Envelopment Analysis (DEA) to Chinese Fish Farms *Aquaculture* 180, 207-221.

Shehadeh Z. H. and M. Pedini, 1999. Issues and Chall n Review of the State of World Aquaculture Issues, FAO. http://www.fao.org/doc rep/003/w7499e/w7499e24.htm

Stifel D., B. Minten and P. Dorosh, 2003. Transaction Costs and Agricultural Productivity: Implications of Isolation for Rural Poverty in Madagascar. Markets and Structural Studies Division. International Food Policy Research Institute. USA.

Soderberg, R. W. 1997. Factors Affecting Fish Growth and Production. pp 199-213 in H. S. Egna and C. E. Boyd, (Eds.), Dynamics of Pond Fish Culture. CRC Press, New York. 437 pp.

Soliman A. K., 2000. Effects of Introducing Ducks into Fish Ponds on Water y, Natural Productivity and Fish Production together with the Economic Evaluation he Integrated and Non-Integrated Systems. *Aquaculture International* 8, 315-326.

Sorgeloos P., 2001. Technologies for Sustainable Aquaculture Development. Plenary Lecture II. In: Subasinghe, P. Bueno, M. . Phillips, C. Hough, S. E. McGladdery and J. R. Arthur., (eds.) Aquaculture in the Third Millennium. Technical Procee s of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. NACA, Bangkok and FAO, Rome.

Sumberg J and C. Okali, 1989. Farmers, On-Farm Research and New Technology. In: Farmer Innovation and Agricultural Research, pp. 109-114. Intermediate Technology Publications, UK.

Swick, R.A. and Cremer, M.C. 2001. Livestock Production: A model for Aquaculture?, Guest Lecture. In R. P. Subasinghe, P. Bueno, M. J. Phillips, C. Hough, S. E. McGladdery and J. R. Arthur, (eds.) Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp.49-60. NACA, Bangkok and FAO, Rome

Tacon A. G. J., 2001. Increasing the Contribution of Aquaculture for Food Security and Poverty Alleviation. In: R. P. Subasinghe, P. Bueno, M. J. Phillips, C. Hough, S. E. McGladdery and J.R. Arthur., Eds. Aquaculture in the Third Millennium. Technical Procee s of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. NACA, Bangkok and FAO, Rome.

Takasaki Y., B. Barham, O. Coomes, 2000. Rapid Rural Appraisal in Humid Tropical Forests An Asset Possession-Based Approach and Validation Methods for Wealth Asses ent Among Forest Peasant Households. *World Development* 28, 1961-1977.

Teichert-Coddington D. R., 1996. Effect of Stocking Ratio on Semi-Intensive Polyculture of *Colossoma macropomum* and *Oreochromis niloticus* in Honduras, Central America. *Aquaculture* 143, 291-302.

Teichert-Coddington D. R., T. J. Popma, L. L. Lovshin, 1997. Attributes of Tropical Pond-cultured Fish, H. S. Egna and C. E. Boyd, Eds., Dynamics of Pond Fish Culture. CRC Press, New York. 437 pp.

Townsley, P., 1996. Rapid Rural Appraisal, Participatory Rural Appraisal and Aquaculture. FAO Fisheries Technical Paper No. 358. Rome, FAO. 109 pp

Uganda Bureau of Statistics (UBoS), 2000. Statistical Abstract, 2000. Uganda Bureau of Statistics, Ministry of Finance, Planning and Economic Development, Kampala, Uganda.

Uganda Bureau of Statistics (UBoS), unpublished. The Nutritional Status of Children in Uganda Now. A Brief Summary of Findings. January, 2001. Uganda National Household Survey (UNHS) Data Set. . Uganda Bureau of Statistics, Ministry of Finance, Planning and Economic Development, Kampala, Uganda.

Uganda Bureau of Statistics (UBoS) and ORC Macro, 2001. Uganda Demographic and Health Survey, 2000-2001. Claverton, Maryland, USA; Uganda Bureau of Statistics, Uganda and ORC Macro, USA.

Uganda Investment Authority (UIA), 2005. http://www.ugandainvest.com/fishing.pdf

UNICEF, 2003. State of the World's Children, 2003. UNICEF, New York.

UNEP, 1990. Environmental Guidelines for Fish Farming. Environmental Guidelines, No. 19. United Nations Environment Programme, Kenya.

University of Stirling, 1998. Methods for Participatory Information Ga hering and Analysis. Working Paper No. 2. Aquaculture in Small-Scale Farmer-Managed Irrigation Systems. DFID Aquaculture Research Programme. Institute of Aquaculture, University of Stirling.

Ulloa, J.B.R. and J.A.J Verreth, 2002. Growth, Feed Utilisation and Nutrient Digestibility in Tilapia Fingerlings (*Oreochromis aureus* Steindachner) Fed Diets Containing Bacteria-Treated Coffee Pulp. *Aquaculture Research* 33, 189-195.

Veerina S.S., M. C. Nandeesha, S. De Silva and M. Ahmed. (1999) An Analysis of Pr duction Factors in Carp Farming in Andra Pradesh, India. *Aquaculture Research* 30, 805-814.

Walakira J., *pers comm*. Fisheries Officer, Wakiso District.

Wanyama J., *pers comm*. Veterinary Officer, Busia District.

Weersink, A., S. Jeffrey, and D. J. Pannell, 2002. Farm-Level Modelling for Bigger Issues. *Review of Agricultural Economics* 24, 123-140.

White H., 2002. Combining Quantitative and Qualitative Approaches in Poverty Analysis. *World Development* 30, 511-522.

World Bank, 1991. Tropical Aquaculture Development, Research Needs. World Bank Technical Paper No. 151, Fisheries Series. The World Bank/United Nations velopment Programme/Commission of the European Communities/Food and Agricultural Organisation.

World Bank, 1996. Staff Appraisal Report. The Republic of Kenya, United Republic of Tanzania and the Republic of Uganda for the Lake Victoria Environment Management Project. Report No. 15429-AFR, World Bank, Washington DC.

World Bank, 2003. Development Data. Country Profile Tables. World Bank, Washington DC.

Wortmann C. S. and C. A. Eledu, 1999. Agro-Ecological Zones of Uganda. A Guide for Planners and Policy Makers. CIAT, The Netherlands.

Yang D.T. and M.Y. An, 2002. Human Capital, Entrepreneurship and Farm Household Earnings. *Journal of Development Economics* 68, 65-88.

Yi Y., 1998. A Bioenergetics Growth Model for Nile Tilapia (*Oreochromis niloticus*) Based on Limiting Nutrients and Fish Standing Crop in Fertilised Ponds. *Aquacultural Engineering* 18, 157-173.

Yi Y., 1999. Modelling Growth of Nile Tilapia (*Oreochromis niloticus*) in a Cage-Cum-Pond Integrated Culture System. *Aquaculture Engineering* 21, 113-133.

Yi, Y., C. K. Lin and J. S. Diana, 1996. Influence Of Nile Tilapia (*Oreochromis niloticus*) Stocking Density In Cages On Their Growth And Yield In Cages And Ponds Containing The Cages. *Aquaculture* 146, 205-215.

Yi Y., C. K. Lin and J. S. Diana, 2003. Hybrid Catfish (*Clarias macrocephalus x C. gariepinus*) and Nile tilapia (*Oreochromis niloticus*) Culture in an Integrated Pen-Cum-Pond System: Growth Performance and Nutrient Budgets. *Aquaculture* 217, 395-408.

Appendices

APPENDIX A: DESCRIPTION OF STUDY AREA

The study was conducted in five of the Lake Victoria B sin districts of Uganda that were randomly selected based on their location within the farming systems as described by NEMA (1999) and Wortman and Eledu (1999) (see figures below . They were:

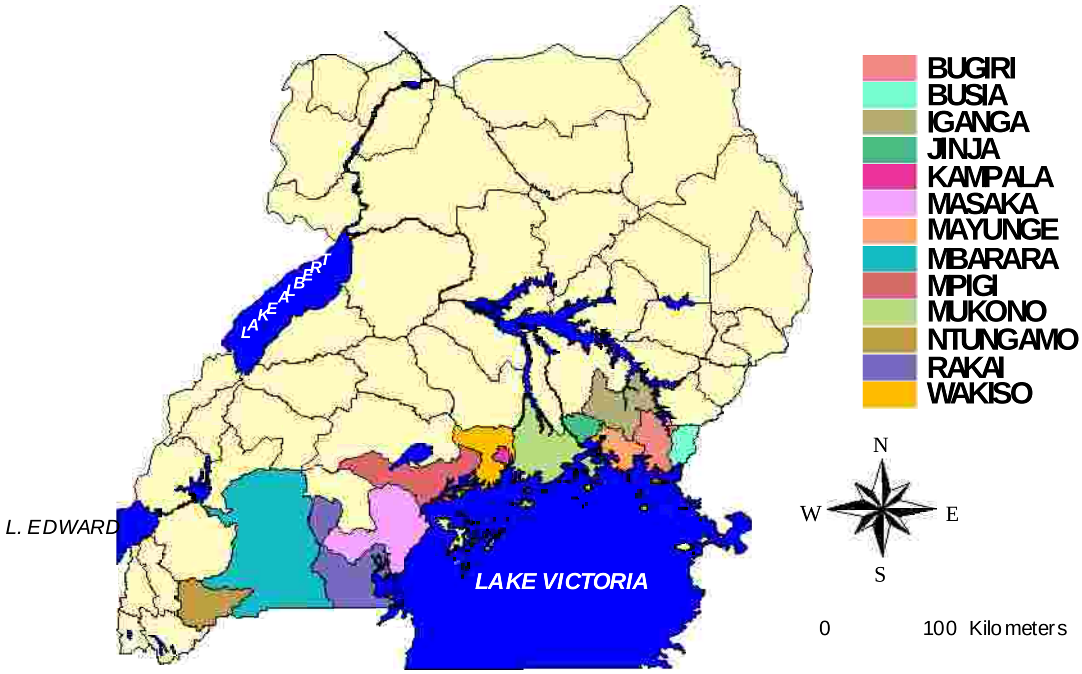
Ntungamo district in the Western Banana-Coffee-Cattle Farming System (WBC).

Kampala and Wakiso districts in the IBC Farming System (IBC).

Busia and Bugiri districts in the BMC Farming system (BMC).

The agroecological zones and farming systems were described based on the influence of local environmental characteristics, land-use patterns, social history, and presence of tsetse fl on the productivity and sustainability of agriculture. The farming systems are regarded as dynamic being subject to changes in local socio-economic factors. Kampala District (the capital of Uganda) and parts of Wakiso District were urban. Thus these two districts in addit ovided a contrast between urban and rural settings.

Districts within the Lake Victoria Basin – Uganda



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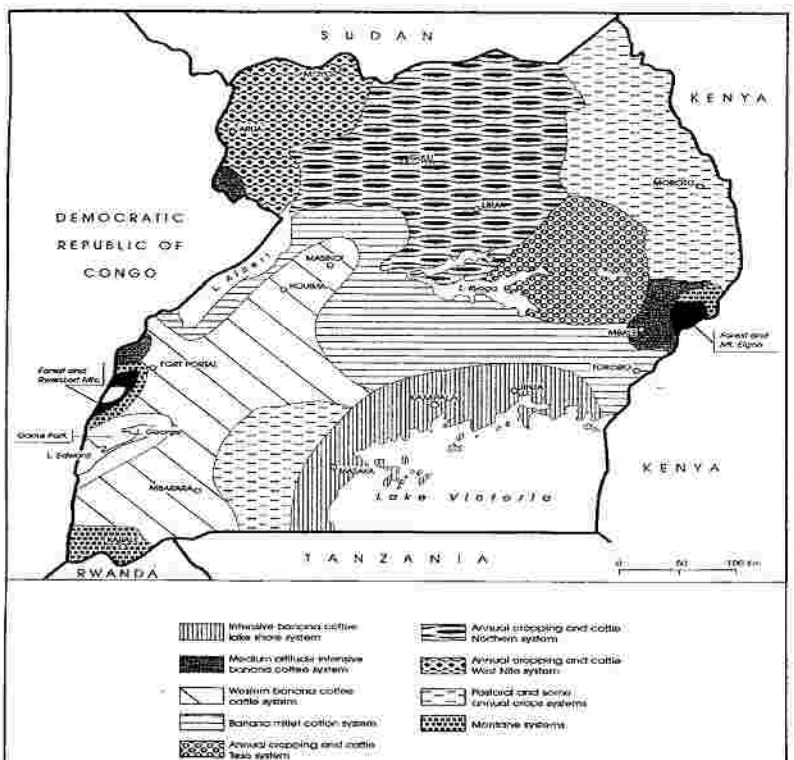
Farming Systems, Uganda (Adapted from MFPED, 1998/99)

Description of Agro-ecological Zones and Farming Systems



[Wortman and Eledu,1999; and NEMA, 1999].

The BMC Farming System lies within the eastern section of Lake Victoria Cres nt. The area lies on a plateau at about 1,174m asl, has average temperat re of more than 20^{o}C and receives above 1,200 mm precipitation per year. The topography consists of less rolling hills with wide valleys. The soils in the are considered less fertile than thos he western part of the same agro-ecological zone. They are typically sandy loam with l w to medium fertility and often acidic especially where K is often deficient. The profitabil ty of response to applied N and P in this area varies and is lower than some other Agro-ecological zones. Soil erodibility is low and rainfall erosivity moderate. 82% of the land in the area is farmed. Wetlands where used for agricultural production are mostly used for rice cultivation. Population density is moderately high (about 280 persons per km^2). Cropping systems are diverse. Cereal and grain legume crops are important as cash crops. Other crops are beans, sweet potato, cassava, maize, rice, Robusta coffee (in parts of Bugiri) and some bananas.

The WBC Farming System lies within the South-Western Grass-Farm Lands in the southern tip and the Bushenyi-N. Rukungiri Farmlands towards the north. The former lies at 1,477m asl, has an average annual temperature of $<20^oC$ and receives less than 1,000mm precipitation per yea as bimodal rainfall. The soils are often moderately acidic clay loam and nutrient supply is considered generally good. Soil is generally shallow on the ridges. Soil erodibility is generally low and rainfall erosivity is low. Water deficits constrain land productivity, especially where soils are shallow. This semi-arid area has roughly equal proportions of grass (Themeda-Chloris grass savannah) and farmland. Population density is moderat (150 persons per km^2). Cropping systems: Banana is the major corp. This is a major ca tle-grazing area.

The Bushenyi-N. Rukungiri Farmlands on the other hand lie at 1,593m asl, have average temperatures of less than or equal to 20^oC and receive 1,000-1,200 mm bimodal rainfall per year. The terrain is undulating with broad ridge tops and ge erally small valleys that may be steeply sloping. There are extensive papyrus swamps. Soils are typically dark, deep and often acidic but nutrient supply is generally good. They are ferralitic clay loams Soil erodibility is low and rainfall erosivity is moderate. This sub-humid highland area is intensively farmed, with some woodland and less grassland interspersed. Population density is moderately high (248 persons per km^2). Temperatures are lower than in the mid-altitude areas of the country. June and July are the driest and coolest months. Rainfall is reliable during the second season. Banana is the major food and market crop. Tea and coffee are important cash crops. Cattle and goat numbers are high. Dairy farming on fenced farms are integrated and cattle feed on crop residues providing some manure in return. Deforestation on steep slopes has resulted in soil erosion and silting of water bodies. Also grown are vegetables, cassava, sweet potatoes, beans.

The IBC Farming System also lies within the Lake Victoria Crescent, west of he Nile. As above the area is about 1174m asl, has average temperature of more that 20^{o}C and receives above 1,200 mm precipitation per year. The landscape in this area comprises an old land surface marked by ridges or laterite-capped hills, long slopes and wide, often papyrus swamp valleys. The soils are variable but often have a high clay loam texture in some places which may interfere with rooting depth. Soils are often ferralitic, acidic and low in K, but with moderate levels of organic matter. Crop production takes place primarily on the slopes where the soil is generally deep. Murram may limit rooting depth in the places on the lower slopes; ridge tops and land fringing swamps are generally not suitable for crop production. 82% of th and is farmed. Soils are degraded because of continuous cropping of small plots in the absence of restorative measures t minimise degradation, especially under the 'mailo[9]' land tenure system. The soils are generally leached. Wetlands are important for plant products, environment l protection and vegetable production. Banana is an important crop but has switched to vegeta owing, poultry and dairying. Bean, sweet potato, cassava and maize are grown as food crop . Robusta coffee is the major cash crop and is still inter-cropped with bananas. Dairy farming on fenced farms and under zero-grazing are integrated and cattle feed on crop residues, providing some manure in return.

[9] 'mailo' tenure is a relic of colonial days, and is a freehold, but often with absentee landlords where the long-term occupants of the land are not the owners.

APPENDIX B: SAMPLING FRAME FOR DATA FROM FARMERS

Number of Fish Farming Units Sampled

District	No. of Fish Farmers (N)*	No. of Fish Farming units Sampled	No. of Checklists Analysed (n)
Busia	35	13	13
Bugiri	6	11	10
Kampala	15	12	11
Wakiso	82	37	26
Ntungamo	74	31	31
TOTAL	212	104	91

***Figures as given by district fisheries records *c.f.* 1999.

Description of Participants in Wealth Rankings

District	Number of Villages	No. of Individual Fish Farmers Ranked	No. of Fish Farmers in Groups Ranked	NUMBER OF FISH FARM UNITS
Bugiri	6	8	5	7
Busia	6	9	12	8
Kampala	7	4	92	10
Wakiso	14	25	37	30
Ntungamo	17	29	18	31
TOTAL	50	75	164	86

Number of Fish Farming Units Sampled for Quantitative Production Data

District	Number of Fish Farming Units	Total Number of Ponds Sampled
Bugiri	13	14
Busia	8	13
Kampala	7	10
Wakiso	7	9
Ntungamo	19	23
TOTAL	54	69

Number of Registered Markets Sampled

District	No. of Major Markets	No. of Minor Markets	Total Markets	No. of Markets Sampled	No. of Consumers	No. of Fish Sellers
Busia	2	2	6	2	9	19
Bugiri	2	2	6	3	25	25
Kampala	9	12	27	4	22	30
Wakiso	2	5	13	2	2	11
Ntungamo	3	0	3	1	39	6
TOTAL	18	21	53	12	97	91

Sample Sizes of Landing Sites and Fishermen to Assess it Demand and Supply

District	Total No. Landing Beaches in District	No. of Landing Beaches Sampled	Number of Fishermen Sampled	Number of Traders in Bait Sampled
Bugiri	74	5	20	10
Busia	4	4	20	
Kampala	3	2	58	
Wakiso	57	3	20	28
Ntungamo	0	0	0	
TOTAL	138	14	118	38

APPENDIX C:QUALITATIVE DATA COLLECTION – PRETESTING TOOLS

CHECKLIST

DISTRICT:
No:
DATE:
RESPONDANT:
ADDRESS:/COUNTY:/SUB-COUNTY:/PARISH:/VILLAGE:
FARM FAMILY:/SIZE:/HEAD:/EDUCATION LEVEL:/AGE:
SOURCES OF INCOME:
Rank source of income in order of importance to family
LAND:/SIZE:/TENURE:/DESCRIPTION OF LAND:/LAND-USE (*maps*) - Indicating area covered (approx.), location on farm, import food/ h crop/animal, income form items if available.
FARM ENTERPRISES: crops, animals, trees, etc/**OBJECTIVES:** overall farm and for individual enterprise

INPUTS:
FERTILISERS:/What fertilisers are used, their source, availability and cost/What are the fertilisers used for on farm, amount used per item if available/What would you fertilise first and why/Which are the preferred fertilisers, why?/
Are fertiliser requirements constant year round
FEEDS/What do you feed/What kind of feed is provided/S rces, availability, costs of feed/feed ingredients/Of the animals on farm which would you rather fe d first, why /Are the same feed provided for the various animals
WATER/Sources of water for the various activities on f rm/Reliability/availability of water supply for the various activities + water quality/Water use conflicts
LABOUR/Sources of labour/Whose engaged in the various activities/Distribution of labour over the various farm activities with time (daily, seasonal)
SEED/Sources of seed, cost and availability/Factors influencing selection of seed, why
KNOWLEDGE (management)/For each activity what, why, source of information, practices, who does it,
Seed selection/Planting/Spacing/Weeding/Pruning/Soil f tility –fertilising + liming/Pest control/disease/Watering
Culling /House management/construction/Site selection/Pasture/pond water/Harvesting
CAPITAL/Investment/Sources

OUTPUT/Amount harvested, regularity/Benefits accruing from enterprise

CONSTRAINTS

Group Discussions with farmers

1 Time Charts

Item/Activity	Long Rainy Season (Mar - June)	Dry Season (July-Aug)	Short Rainy Season (Sept - Nov)	Dry Season (Dec - Feb)
Major Activities				

2 Resource Flows

3 Transects

Natural resources	Upland	Upland	Mid-land	Lowland
Soil Type				
Water Source				

APPENDIX D: TOOLS USED FOR RAPID APPRAISALS

Potential For Farming Indigenous Species, Description Fish Farming Systems, Identification Of Resources Available To Farmers

District:
No:
DATE:
RESPONDENT:
ADDRESS: county, sub-county, parish, village
FARM FAMILY: Size, Name Household Head, Education level of household head, Sex house hold head, Age house hold head
SOURCES OF INCOME: Rank source of income
LAND: Size, tenure, description of land, land -use maps, indicate area covered by activity, important food/cash crop/animal, income from items if available
FARM ENTERPRISES: *Objectives, Inputs*

AQUACULTURE:
Number of ponds, sizes, cost of construction, who did ruction.
FERTILISERS:/What fertilisers are used, their source, availability and cost/What are the fertilisers used for on farm, amount used per item if available/What would you fertilise first and why/Which are the preferred fertilisers, why?/Are fertiliser requirements constant year round
FEEDS/What do you feed/What kind of feed is provided/S rces, availability, costs of feed/feed ingredients/Of the animals on farm which would you rather feed first, why/Are the same feed provided for the various animals
WATER/Sources of water for the various activities on f rm/Reliability/availability of water supply for the various activities + water quality/Water use conflicts
LABOUR/Sources of labour/Whose engaged in the various activities/Distribution of labour over the various farm activities with time (dai seasonal)
SEED/Sources of seed, cost and availability/Factors influencing selection of seed, why/Species/variety farmed
CAPITAL/Investment/Sources

OUTPUT/Amount harvested, regularity/Benefits accruing from enterprise/Are the fish of uniform at harvest/what sizes are marketable
KNOWLEDGE/ Do you think the knowledge you have on aquaculture is adequate?

Constraints

What crops do you grow? Objectives, feeds, seed, harvest, by-products and what they are used for.
What animals do you keep? Objective, feeds, yield, what the manure is used for.

DISTRICT EXTENSION CO-ORDINATOR

Name of District:

Area of District:

Number of counties in District: ………………………………………………………

Agricultural Profile of District

What are the agro-ecological zones in your District? What are the farming systems in your district?

What are the major agricultural activities in your district?

Have you ever done any assessments of any of the agr cultural activities in your Districts? (*If so, what were the reasons they were done? methods used?)*

What is your opinion of the results obtained from the methods you used?

What benefits are derived from aquaculture in your Distric ?

Does it make a significant contribution to your distri t's agricultural profile? (Please rank in order of importance: crop/livestock/lake fisheries/aquaculture)

Who are the main beneficiaries of aquaculture production?

Which NGOs or CBOs are involved in aquaculture and/or agriculture in your district?

What is your district's Policy towards aquaculture?

What is your personal opinion of aquaculture in your district?

Are there specific issues related to gender and agriculture in your District?

DISTRICT FISHERIES OFFICER

The general status of the fisheries sector in your dis rict

What is the relative contribution of the fisheries sector (both natural and aquaculture) to your District?

Of the contribution of the fisheries sector, how much does aquacultur contribute to the fisheries sector?

What is your perception of aquaculture's contribution our district's economy? (Significant/insignificant)

Fisheries

At what scale are fisheries and aquaculture practised in your district?

What physical resources are available that affect production of the fisheries?

What factors affect the accessibility of fishermen to ese resources?

Is there seasonal variation in catch, composition of c tch and price of fish?/in which water bodies/trends in catch

Markets and marketing

What is the average price of fish in your district? Sp cies/unit cost

How does it compare to other sources of animal protein? Type/unit cost/

Which is the most favoured/marketable of the species for human consumption? (If possible give reasons. Species/reasons for rating)

Which is the most favoured market size of fish in your district? (Species/minimum size accepted on market)

Other uses of fish in your district?

How much fish is consumed within your district and how much of it is exported?

Does your District import fish? If so how much and wh t for? (Species /quantity/ purpose)

Aquaculture

How many fish ponds are in your District? County/numbe f ponds/ Number of fish Farming Households or groups

What are the main reasons farmers adopt fish farming?

How do most farmers come to learn about fish farming?

Who owns the fish ponds? Who runs/manages the fish ponds on a day –to-day basis?

What resources do most farmers invest into aquaculture in your district?

What sort of fish farmers do you have (small scale, subsistence, etc.)

What inputs are most readily available for aquaculture in your district? (source/ type/ availability/cost: rank in order of importance)

What management practices (including harvesting) do the majority of fish farmers in your district undertake? why? (constraints? Yields?)

Who are the major beneficiaries from fish farming in your District?

What are your district's policies towards fish farming?
What is your personal assessment of fish farming your district?

Biodiversity

What species of fish do you have in your district's wa ers?
Of these which species are harvested for market?
What is their trend in catches and yields?
Have you realised a decline in fish diversity over the years? (details of species/year)
Of what significance is the fish or the change in fish biodiversity to (specify – income, adoption, etc.):-
Which fish species are most preferred locally? And why?
Have you observed an effect of trends in the fishery o aquaculture?

FISH MARKETS - CONSUMERS

Name of enumerator

Questionnaire Number (i.e. no. on questionnaire)

1. District, county, sub-county, parish, town
2. Name of market and location
3. What type of market is this? retail/wholesale/both
4. What type of goods are traded in this market? general merchandise/food only/fish only/other merchandise
5. Name/sex of consumer
6. What type of consumer are you? (Family/ taurant/institution)
7. How many are you in your establishment?
8. How old are you?
9. What level of education do you have?
10. What type of job do you have?
11. Do you live/work/is your institution/ is your restaurant near this market?
12. How much fish have you bought today?
13. How many fish do you normally buy each time?
14. How many times do you buy/consume fish in a month?
15. Which type of fish do you/your family/customers like most? (Rank)
16. What are your reasons for the above choices?
17. How much does the fish cost?
18. At which season is the fish you prefer scarce or expensive?
19. Do you consider the fish you buy affordable?
20. Which fish do you consider the most valuable?
21. If you were short of cash, of the items listed which would you rather buy?
22. What are your reasons for purchasing the above items when you are short of cash?
23. What is the most important processed form in you prefe your fish?
24. Do you prefer your fish whole, filleted or both?
25. What sizes of fish do your customers prefer?
26. Where do you purchase most of your fish from?

FISH MARKETS - TRADERS

Name of enumerator

Questionnaire Serial Number

1 Location: district, county, sub-county, parish and town

2 Name and location of market

3 What type of market is this? (Retail/wholesal /both)

4 What types of goods are traded in this market?

5 What type of trader are you? (Retailer/wholesa er/both)

6 How do you measure the fish you trade in?

7 What fish do you trade in? (Rank most important)

8 What is the most important processed form in which you sell your fish?

9 In what form do you sell the fish you trade in?

10 With respect to the fish you trade in, which form do you sell most?

11 Why do you trade in these forms?

12 Where do you get the fish you sell in the market?

13 When are the periods when the supply of the fish you t s low at source?

14 What is the dry season cost price from your supplier?

15 What is the wet season cost price from your supplier?

16 What are the sizes of fish for which you have quoted the above prices?

17 When is the demand highest?

18 What sizes of fish do your customers prefer?

19 What category of customers prefers the sizes and types of fish you have mentioned?

20 What are the fluctuations in selling price?

21 When is the demand lowest?

APPENDIX E: PRODUCTION DATA – FARMERS

District/county/sub-county/parish/village

1 Name/age/sex

2 Experience in fish farming (years)

3 Total land area (acres)

4 Number of parcels of land/proximity to each other

5 Ponds:

- number/size/average depth/dykes
- date constructed/age of pond (in years)
- date first stocked (in years)
- source of water/pH/ iron (Fe) mg/l

6 Stocking:

- species stocked
- number stocked
- date stocked
- size at stocking
- source of stock
- total cost of stock

7 Feeds Used by Farmers per Pond:

- do you feed
- feed type
- quantity
- source of brewers waste used
- cost of brewers waste
- how frequently do you feed the brewers waste

8 Fertilisation:

- do you fertilise ponds? (yes/no)
- what do you use?
- unit of quantity
- amount fertilised (e.g. 1 bundle, 1 kg, etc.)
- source
- cost
- how frequently do you use it?

9 Sampling/Harvest:

- species
- number
- total weight
- average weight
- average length
- number of cohorts
- culture period (months)

10 Labour source:

- estimate of amount of labour used per month
- estimate of cost of labour

APPENDIX F: QUALITATIVE DATA ANALYSES

Cross-Tabulation and Chi-Square Test of Association

The null hypothesis: there was no association between the expected frequencies for each observation in the table.

The expected frequency was calculated as:

E_{ij} = [(total of row *i*) * (total of column *j*)] / total number of observations

The total χ^2 was calculated in the Minitab package by:

$$\sum_{I}\sum_{j} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

where O_{ij} = observed frequency in cell (*i, j*) and E_{ij} = expected frequency for cell (*i, j*).

The degrees of freedom associated with the contingency tables possessing r rows and c columns equalled (r - 1)(c - 1). The contribution from each cell to the χ^2 statistic was:

$$\text{Standardised residual} = \frac{\text{observed count - expected count}}{\sqrt{\text{expected count}}}$$

The χ^2 contribution from each cell is used to analyse how different cells contribute to a judgement about the degree of association.

Kruskal-Wallis Test

The Kruskal-Wallis test is a non-parameteric test used to analyse differences among populations medians.

The Kruskal-Wallis procedure tests:

H:$h_1 = h_2 = h_3$, versus

H_1: not all h's are equal, where the h's are the population means.

Minitab calculates the test statistic, H, by first ranking the c samples, with the smallest observation given rank 1, the second smallest 2, etc. If two or more observations are tied, the average rank is assigned to each before calculating the test statistic as:

$$H = \frac{1\,2\Sigma\, n_i[R_i - R]^2}{N(N + 1)}$$

where, n_i is the number of observations in group i,
N is the total sample size,
i is the average of the ranks in group i, and
R_i is the average of all the ranks.

APPENDIX G: MULTIVARIATE DATA REDUCTION

Multivariate Analysis

Principle Component Analysis is concerned with examining the interdependence of variables arising on an equal footing. The idea is to transform the p observed variables to p new, orthogonal variables, called principal components, which are linear combinations of the original variables ($\mathbf{a}^{\mathbf{T}}\mathbf{X} = \Sigma \mathrm{a}_i X_i$) and which are chosen in turn to explain as much of the variation as possible. Thus th st component $\mathbf{a_1}^{\mathbf{T}}\mathbf{X}$ is chosen to have maximum variance, subject to $\mathbf{a_1}^{\mathbf{T}}\ \mathbf{a_1} = 1$, and is often some sort of average of the original variables Chatfield, (1995).

Description of the Variables from Quantitative sub-Sample used in Principle Component Analysis

Variable	Units
State Variables	
O. niloticus:	Stocking density of *O. niloticus* (no. ha^{-1})
C. gariepinus:	Stocking density of *C. gariepinus* (no. ha^{-1})
O. niloticus and *C. gariepinus:*	Stocking density of *O. niloticus* and *C. gariepinus* (no. ha^{-1})
All fish types:	Stocking density of all fish species farmed (no. ha^{-1})
cow dung	kg/ha/yr
chicken dropping	kg/ha/yr
goat droppings	kg/ha/yr
other animal manure	kg/ha/yr
compost	kg/ha/yr
maize bran	kg/ha/yr
rice bran	kg/ha/yr
wheat bran	kg/ha/yr
Termites	kg/ha/yr
fish meal	kg/ha/yr
fish intestines	kg/ha/yr
Weeds	kg/ha/yr
cooked maize meal (‘*posho*’)	kg/ha/yr
millet flour	kg/ha/yr
Cassava	kg/ha/yr
household waste	kg/ha/yr
cassava leaves	kg/ha/yr
yam (taro) leaves	kg/ha/yr
Galisoga pariflora (kafumbe grass)	kg/ha/yr
sweet potato leaves	kg/ha/yr
rumen content	kg/ha/yr
blood and abattoir waste	kg/ha/yr
cotton seed cake	kg/ha/yr
sunflower seed cake	kg/ha/yr
Bread	kg/ha/yr
organic input	kg/ha/yr
protein input	kg/ha/yr
nitrogen input	kg/ha/yr
Rate Variables	
area of farm	approx. acres
area of pond	m^2
depth of pond	M
age of seed	dummy (fingerlings = 1, young = 2, adult = 3)
fertilisation frequency	dummy (none = 0, weekly = 1, fortnightly = 2, several a week = 3, monthly = 4, irregularly = 5)
Fertilisation strategy	dummy (single = 1, mixed = 2)
feeding frequency	dummy (none = 0, daily = 1, weekly = 2, fortnightly = 3, several times a week = 4, monthly = 5, irregularly = 6)
feeding strategy	dummy (single = 1, mixed = 2)
culture period	Months
Intrinsic variables	
age of farmer	approx. years
experience as fish farmer	approx. years
age of pond	approx. years
Agro-ecological zone	dummy variable (BMC -FS = 1, MAIBC-FS = 2, WBC = 3)
wealth ranking	Scores
Yield	kg/ha/yr

Quality of Farmers Feedstuffs

Feedstuff	% CP	% CF
Ants/termites	36.04	1.08
Cassava leaves	30.99	8.72
Cotton seed cake	13.02	11.54
G. pariflora (Kafumbe grass)	22.43	14.90
Maize bran	13.72	18.21
Rice bran	10.12	18.32
Sweet potato leaves	20.37	15.94
Water plants	12.43	3.56
Coco yam leaves	19.50	17.84
Sunflower seed cake*	34.10	13.20
Fish Meal	78.52	18.03
Cassia sp. Leaves*	17.90	24.70
Brewers waste*	27.80	12.60
Russian comfrey*	19.00	14.00
Sorghum flour	10.03	2.10
Pumpkins	31.60	19.72
Banana peelings (fresh)	7.91	7.72
Cassava	25.82	15.24

* Values for feedstuffs with an asterix are estimates by Göhl, 1981.

APPENDIX H: EXPERIMENTAL PONDS

Pond Bottom Soil

Pond Number	Treatment No.	Block	Bush	pH	% Organic Matter	Total N (%)	Total P (%)	Available P (ppm)	K (mg/ 100g)	Na (mg/ 100g)	Ca (mg/ 100mg)	% Sand	% Clay	% Silt
F3	1	1	0	5.4	2.1	0.13	0.71	69.8	5.9	9.7	10	53.1	33.2	13.6
F4	2	1	0	4.5	0.9	0.08	0.31	27.9	2.4	6	3	53.1	25.2	21.6
F5	3	1	0	4.4	1	0.17	0.66	16.8	3.1	8.1	6	47.1	41.2	11.6
F8	4	1	0	4.5	1.8	0.13	0.57	40.9	2.8	6.9	2.8	73.1	21.2	5.6
F9	3	2	0	4.6	1.4	0.15	0.47	35.4	3.5	7.9	5	67.1	25.2	7.6
F10	4	2	0	4.5	2.7	0.3	0.45	29.8	4.2	11.6	4.8	69.1	27.2	3.6
F11	2	2	1	4.3	3.3	0.27	0.36	11.6	4.2	23.1	5.3	49.1	31.6	19.3
F12	1	2	1	4.5	3.5	0.17	0.36	12.1	4.7	14.8	7.3	37.1	35.6	27.3
F13	1	3	1	4.5	2.8	0.25	0.33	28.9	3.3	9	3.5	53.1	27.6	19.3
F17	2	3	1	4.5	3.7	0.17	0.52	30.7	4.5	11.3	5.8	49.1	31.6	19.3
F18	4	3	1	4.6	4.6	0.33	0.28	16.3	6.1	13.6	6.3	27.1	43.6	29.3
F19	3	3	1	4.5	2.9	0.18	0.26	34	4.2	16.2	4.8	61.1	27.6	11.3

APPENDIX I: POND SAMPLING – EXPERIMENTS

EXPERIMENT 1: Effect of Stocking Density on Yield

Analysis of Variance (General Linear Model)

Y-variable	Variance between Blocks p-value	Variance between Sample Point p-value	Variance between Treatment p-value
Feed conversion	0.56	0.22	0.42
Pond Biomass (kg)	0.64	0.00	0.00
Average Weight (g)	0.21	0.00	0.00
Average Length (cm)	0.01	0.00	0.21
Average Body weight ($g^{0.8}$)	0.25	0.00	0.00
Growth in Length	0.10	0.06	0.74
Growth in weight	0.39	0.00	0.29
Growth Rate ($g.d^{-1}$)	0.48	0.00	0.30
Relative Growth Rate	0.24	0.00	0.91
Specific Growth Rate	0.54	0.00	0.96

Yields after 124 Days Production

Parameter	Treatment			
	I	II	III	IV
Stocking				
Density (fish/m^2)	1	2	3	4
Total no. of fish/pond	600	1200	1800	2400
Mean weight (g/fish)	1.27 ± 0.13	1.08 ± 0.09	1.03 ± 0.03	1.00 ± 0.06
Total weight (kg)	0.76 ± 0.07	1.30 ± 0.11	1.87 ± 0.05	2.41 ± 0.14
Mean total length (cm/fish)	4.11 ± 0.10	3.99 ± 0.10	3.91 ± 0.13	3.96 ± 0.05
Harvest				
Mean weight (g/fish)	70.59 ± 10.71	44.31 ± 11.11	45.41 ± -	49.54 ± 9.13
Total weight (kg)	42.35 ± 6.43	53.17 ± 13.33	81.74 ± -	118.90 ± 21.91
Mean total length (cm/fish)	15.52 ± 0.64	13.12 ± 1.16	13.44 ± -	13.90 ± 0.70
FCR	1.23 ± 0.28	1.35 ± 0.03	1.06 ± -	1.04 ± 0.35
Gains				
Mean weight gain (g/fish)	69.32 ± 10.78	43.23 ± 12.33	44.43 ± -	48.59 ± 9.19
Daily weight gain (g/fish/day)	0.56 ± 0.09	0.34 ± 0.10	0.36 ± -	0.39 ± 0.07
Mean total length gain (cm/fish)	11.41 ± 0.61	8.13 ± 2.08	9.79 ± -	9.95 ± 0.64
Daily total length gain (cm/fish/d)	0.09 ± 0.00	0.07 ± 0.02	0.08 ± -	0.08 ± 0.00
Total weight gain (kg)	41.49 ± 6.47	50.37 ± 14.64	79.97 ± -	116.60 ± 22.04
Net yield (kg/m^2)	0.07 ± 0.01	0.08 ± 0.02	0.13 ± -	0.19 ± 0.03
Net yield (t/ha/year)	2.04 ± .32	2.47 ± 0.72	3.92 ± -	5.71 ± 1.08
Gross yield (kg/m^2)	0.07 ± 0.01	0.09 ± 0.02	0.14 ± -	0.20 ± 0.03
Gross yield (t/ha/year)	1.85 ± 0.28	2.32 ± 0.58	3.57 ± -	5.20 ± 0.96

Factor Analysis, Experiment 1

Principal Component Factor Analysis of the Correlation Matrix

Un-rotated Factor Loadings and Communalities

19 cases used 65 cases contain missing values

Variable	*Factor1*	*Factor2*	*Factor3*	*Factor4*	*Communality*
Sample P	0.912	-0.060	0.284	0.215	0.962
block no	0.593	-0.346	-0.275	0.157	0.572
treatment	0.012	0.886	-0.264	-0.205	0.897
biomass	0.862	0.412	-0.131	-0.048	0.933
gl	0.275	-0.156	0.462	-0.811	0.971
gw	0.883	-0.220	-0.049	0.127	0.847
total fe	0.762	0.498	-0.266	-0.138	0.919
manure	-0.719	0.410	0.141	0.458	0.915
Oxygen m	0.743	0.111	0.459	0.406	0.941
pH	0.111	-0.324	-0.911	-0.016	0.947
Variance	4.4456	1.6842	1.5906	1.1829	8.9033
% Var	0.445	0.168	0.159	0.118	0.890

Factor Score Coefficients

Variable	*Factor1*	*Factor2*	*Factor3*	*Factor4*
Sample P	0.205	-0.036	0.179	0.182
block no	0.133	-0.205	-0.173	0.133
treatment	0.003	0.526	-0.166	-0.173
biomass	0.194	0.245	-0.082	-0.041
gl	0.062	-0.093	0.290	-0.685
gw	0.199	-0.131	-0.030	0.107
total fe	0.171	0.296	-0.167	-0.116
manure	-0.162	0.244	0.089	0.388
Oxygen m	0.167	0.066	0.289	0.343
pH	0.025	-0.192	-0.573	-0.013

PRODUCTION RESULTS EXPERIMENT 2: The Effect of Varying Cow Dung and Maize Bran Input Levels on Pond Yield and Returns in *O. niloticus-C. gariepinus* Polyculture.

Analytical Procedure Used to Correct for Missing Variables and Outliers

Weight Time Relationships.

Equations Used To Estimate Above Weights for Treatment

Treatment	*O. niloticus*		*C. gariepinus*	
I	$y = 4.3891e^{0.0175x}$ $R^2 = 0.75$	$y = 0.5664x - 1.0309$ $R^2 = 0.66$	$y = 10.834e^{0.014x}$ $R^2 = 0.78$	$y = 0.7817x - 3.3824$ $R^2 = 0.68$
II	$y = 3.6451e^{0.0206x}$ $R^2 = 0.78$	$y = 0.6835x - 0.7288$ $R^2 = 0.79$	$y = 6.4649e^{0.0176x}$ $R^2 = 0.92$	$y = 1.2961x - 42.104$ $R^2 = 0.85$
III	$y = 5.9419e^{0.0159x}$ $R^2 = 0.70$	$y = 0.5311x + 2.548$ $R^2 = 0.72$	$y = 7.6959e^{0.0192x}$ $R^2 = 0.90$	$y = 1.8374x - 64.623$ $R^2 = 0.84$
IV	$y = 3.7467e^{0.0189x}$ $R^2 = 0.83$	$y = 0.6877x - 13.48$ $R^2 = 0.93$	$y = 12.303e^{0.0151x}$ $R^2 = 0.84$	$y = 1.5024x - 47.935$ $R^2 = 0.61$
V	$y = 2.9579e^{0.0194x}$ $R^2 = 0.85$	$y = 0.6849x - 20.169$ $R^2 = 0.84$	$y = 8.6642e^{0.0191x}$ $R^2 = 0.85$	$y = 2.3868x - 98.431$ $R^2 = 0.78$
VI	$y = 8.981e^{0.0163x}$ $R^2 = 0.76$	$y = 0.9757x - 6.2788$ $R^2 = 0.99$	$y = 10.852e^{0.02x}$ $R^2 = 0.84$	$y = 2.6398x - 54.133$ $R^2 = 0.97$

Equations Used To Estimate Above Lengths for Treatment

Treatment	*O. niloticus*	*C. gariepinus*
I	$y = 2.3886x - 0.9653$ $R^2 = 0.91$	$y = 2.804x - 1.8506$ $R^2 = 0.96$
II	$y = 2.6096x - 1.1428$ $R^2 = 0.94$	$y = 2.6526x - 1.6428$ $R^2 = 0.96$
III	$y = 2.5355x - 1.1407$ $R^2 = 0.89$	$y = 2.6638x - 1.6491$ $R^2 = 0.95$
IV	$y = 2.7353x - 1.3877$ $R^2 = 0.94$	$y = 2.7781x - 1.8101$ $R^2 = 0.99$
V	$y = 2.602x – 1.225$ $R^2 = 0.95$	$y = 2.7076x - 1.6675$ $R^2 = 0.95$
VI	$y = 2.6641x - 1.3204$ $R^2 = 1.00$	$y = 3.0018x - 2.1057$ $R^2 = 0.99$

Growth Performance, *O. niloticus*

Parameter	*O. niloticus* I	II	III	IV	V	VI
Stocking						
Density (fish/m^2)	2	2	2	2	2	2
Total no. of fish	1200	1200	1200	1200	1200	1200
Mean weight (g/fish)	1.64 ± 0.16	1.48 ± 0.00	1.48 ± 0.00	1.36 ± 0.12	1.48 ± 0.00	1.48 ± -
Total weight (kg)	1.96 ± 0.19	1.78 ± 0.00	1.78 ± 0.00	1.63 ± 0.14	1.78 ± 0.00	1.78 ± -
Total length (cm)	3.03 ± 0.63	3.66 ± 0.00	3.66 ± 0.00	3.66 ± 0.00	3.66 ± 0.00	3.66 ± -
Harvest						
Mean weight (g/fish)	172.80 ± 49.98	182.77 ± 24.09	137.51 ± 20.96	141.80 ± 18.83	209.85 ± 67.66	228 ± -
Total Weight (kg)	207.36 ± 59.98	219.32 ± 28.91	165.01 ± 25.14	170.16 ± 22.60	251.82 ± 81.19	273.77 ± -
Total length (cm)	23.11 ± 4.62	19.95 ± 0.67	19.29 ± 0.16	19.66 ± 0.75	21.98 ± 2.78	24.14 ± -
Gain						
Mean weight gain (g/fish)	171.16 ± 49.83	181.29 ± 24.09	136.03 ± 20.96	140.44 ± 18.81	208.37 ± 67.66	226.66 ± -
Daily weight gain (g/fish/d)	0.71 ± 0.21	0.75 ± 0.10	0.56 ± 0.09	0.58 ± 0.08	0.86 ± 0.28	0.94 ±
Total weight gain (kg)	205.40 ± 59.79	217.54 ± 28.91	163.23 ± 25.14	168.35 ± 22.61	250.04 ± 81.19	271.99 ± -
Net yield (kg/m^2/crop)	0.34 ± 0.10	0.36 ± 0.05	0.27 ± 0.04	0.28 ± 0.03	0.30 ± 0.03	0.45 ± -
Net yield (t/ha/year)	5.19 ± 1.51	5.49 ± 0.73	4.12 ± 0.64	4.25 ± 0.57	4.62 ± 0.44	6.87 ±
Gross yield (kg/m^2/crop)	0.35 ± 0.10	0.37 ± 0.05	0.28 ± 0.04	0.28 ± 0.04	0.42 ± 0.13	0.46 ± -
Gross yield (t/ha/year)	5.24 ± 1.51	5.54 ± 0.73	4.17 ± 0.63	4.30 ± 0.57	6.36 ± 2.05	6.92 ± -
Mean length gain (cm/fish)	20.08 ± 5.25	16.29 ± 0.68	15.63 ± 0.16	16.00 ± 0.75	18.32 ± 2.78	20.48 ± -

Growth Performance, *C. gariepinus*.

Parameter	*C. gariepinus* I	II	III	IV	V	VI
Stocking						
Density (fish/m^2)	1	1	1	1	1	1
Total no. of fish	600	600	600	600	600	600
Mean weight (g/fish)	5.14 ± 0.01	4.22 ± 0.74	4.37 ± 0.76	6.28 ± 1.15	5.00 ± 0.13	3.31 ± -
Total weight (kg)	3.09 ± 0.00	2.48 ± 0.55	2.62 ± 0.46	3.77 ± 0.69	3.00 ± 0.08	1.99 ± -
Total length (cm)	8.34 ± 0.64	6.79 ± 0.75	6.57 ± 1.13	8.45 ± 0.75	8.10 ± 0.40	6.93 ± -
Harvest						
Mean weight (g/fish)	292.17 ± 52.91	359.04 ± 0.55	371.08 ± 49.33	408.10 ± 121.12	729.41 ± 73.86	582.06 ± -
Total Weight (kg)	175.30 ± 31.75	215.42 ± 41.78	222.65 ± 29.60	244.86 ± 72.68	437.64 ± 44.32	349.24 ± -
Total length (cm)	32.87 ± 3.43	38.36 ± 1.37	38.04 ± 0.98	37.99 ± 4.51	46.70 ± 4.26	42.17 ± -
Gain						
Mean weight gain (g/fish)	287.03 ± 52.91	354.83 ± 0.19	366.71 ± 48.67	401.82 ± 122.19	758.01 ± 71.64	578.75 ± -
Daily weight gain (g/fish/d)	1.19 ± 0.22	1.47 ± 0.00	1.52 ± 0.20	1.67 ± 0.51	3.36 ± 0.64	2.40 ± -
Total weight gain (kg)	172.22 ± 31.75	212.90 ± 0.11	220.03 ± 29.20	241.10 ± 73.31	434.64 ± 44.25	347.25 ± -
Net yield (kg/m^2/crop)	0.29 ± 0.05	0.35 ± 0.00	0.37 ± 0.05	0.40 ± 0.12	0.72 ± 0.08	0.58 ± -
Net yield (t/ha/year)	4.35 ± 0.80	5.38 ± 0.00	5.56 ± 0.74	6.09 ± 1.85	10.98 ± 1.12	8.77 ± -
Gross yield (kg/m^2/crop)	0.29 ± 0.05	0.36 ± 0.00	0.37 ± 0.05	0.41 ± 0.12	0.73 ± 0.08	0.58 ± -
Gross yield (t/ha/year)	4.43 ± 0.80	5.44 ± 0.00	5.62 ± 0.75	6.19 ± 1.83	11.05 ± 1.12	8.82 ± -
Mean length gain (cm/fish)	24.53 ± 3.41	30.83 ± 1.24	31.47 ± 1.28	29.54 ± 5.25	38.59 ± 4.55	35.24 ± -

Growth Performance, all species combined

Parameter	Overall I	II	III	IV	V	VI
Stocking						
Density (fish/m^2)	3	3	3	3	3	3
Total no. of fish	1800	1800	1800	1800	1800	1800
Mean weight (g/fish)	2.81 ± 0.11	2.39 ± 0.25	2.44 ± 0.25	3.00 ± 0.43	2.65 ± 0.04	2.09 ± -
Total weight (kg)	5.05 ± 0.20	4.31 ± 0.45	4.40 ± 0.46	5.40 ± 0.79	4.78 ± 0.08	3.76 ± -
Harvest						
Mean weight (g/fish)	212.59 ± 39.98	241.52 ± 15.88	215.36 ± 2.75	230.57 ± 47.70	323.08 ± 19.41	346.11 ± -
Total Weight (kg)	382.66 ± 71.96	434.74 ± 28.57	387.65 ± 4.95	415.02 ± 85.86	740.41 ± 173.30	623.0 ± -
FCR	0	0.47 ± 0.13	2.13 ± 0.31	2.87 ± 0.32	1.71 ± 0.16	2.65 ± -
Gain						
Mean weight gain (g/fish)	209.79 ± 39.89	239.13 ± 16.13	212.92 ± 2.60	227.56 ± 48.13	320.43 ± 19.36	344.02 ± -
Daily weight gain (g/fish/d)	0.87 ± 0.17	0.99 ± 0.07	0.88 ± 0.01	0.94 ± 0.22	1.33 ± 0.08	1.43 ± -
Total weight gain (kg)	251.74 ± 47.86	286.96 ± 19.35	255.51 ± 3.13	273.03 ± 57.76	441.00 ± 33.99	412.83 ± -
Net yield (kg/m^2/crop)	0.42 ± 0.08	0.48 ± 0.03	0.43 ± 0.00	0.06 ± 0.10	0.74 ± 0.06	0.69 ± -
Net yield (t/ha/year)	6.36 ± 1.21	7.25 ± 0.49	6.45 ± 0.08	6.90 ± 0.14	11.14 ± 0.86	10.43 ± -
Gross yield (kg/m^2/crop)	0.64 ± 0.12	0.72 ± 0.05	0.65 ± 0.00	0.69 ± 0.14	0.97 ± 0.06	1.04 ± -
Gross yield (t/ha/year)	9.67 ± 1.82	10.98 ± 0.72	9.79 ± 0.13	10.48 ± 2.17	14.69 ± 0.88	15.74 ± -

Factor Analysis Experiment 2: days, treatment, *O. niloticus* weight, *O. niloticus* growth weight, *O. niloticus* growth length, *C. gariepinus* av. weight

Principal Component Factor Analysis of the Correlation Matrix

Unrotated Factor Loadings and Communalities

123 cases used 72 cases contain missing values

Variable	*Factor1*	*Factor2*	*Factor3*	*Factor4*	*Factor5*	*Communality*
days	-0.864	-0.357	-0.134	-0.003	-0.070	0.897
treatment	-0.193	0.656	-0.357	0.444	0.261	0.861
on weigh	-0.881	-0.212	0.073	-0.159	0.038	0.852
on grth	-0.503	0.362	0.430	-0.373	0.164	0.734
on grth	0.111	0.493	0.461	-0.228	0.295	0.608
cg av. w	-0.938	0.050	0.074	0.065	-0.063	0.897
cg grth	-0.634	0.455	0.369	-0.207	-0.193	0.824
cg grth	-0.137	0.572	0.391	-0.052	-0.368	0.636
pond bio	-0.966	-0.064	0.078	-0.031	-0.022	0.945
feed (kg)	-0.665	0.427	-0.019	0.133	0.186	0.677
total ma	0.378	-0.371	0.330	-0.581	-0.061	0.731
tot rain	-0.641	-0.408	-0.150	0.067	-0.052	0.607
amb temp	0.579	0.324	-0.092	-0.001	0.112	0.461
leakage	0.192	-0.232	0.295	-0.163	0.647	0.624
SD	0.546	-0.002	0.445	0.082	-0.256	0.569
tot macr	0.202	-0.051	0.227	0.269	-0.044	0.169
DO (mgl-	-0.406	-0.124	-0.348	-0.393	0.168	0.484
temp	0.099	0.358	-0.573	-0.373	-0.389	0.757
condv	0.304	0.160	-0.408	-0.530	-0.013	0.565
pH	0.020	0.286	-0.572	-0.207	0.200	0.492
Variance	6.0326	2.4168	2.2687	1.5463	1.1259	13.3903
% Var	0.302	0.121	0.113	0.077	0.056	0.670

Factor Score Coefficients

Variable	*Factor1*	*Factor2*	*Factor3*	*Factor4*	*Factor5*
days	-0.143	-0.148	-0.059	-0.002	-0.062
treatment	-0.032	0.272	-0.157	0.287	0.232
on weigh	-0.217	-0.100	0.047	-0.112	0.025
on grth	-0.083	0.150	0.189	-0.241	0.146
on grth	0.018	0.204	0.203	-0.148	0.262
cg av. w	-0.253	0.004	0.054	0.029	-0.068
cg grth	-0.105	0.188	0.163	-0.134	-0.171
cg grth	-0.023	0.236	0.172	-0.034	-0.327
pond bio	-0.000	-0.000	0.000	-0.000	-0.000
feed (kg	-0.110	0.177	-0.009	0.086	0.165
total ma	0.063	-0.154	0.145	-0.376	-0.054
tot rain	-0.106	-0.169	-0.066	0.043	-0.046
amb temp	0.096	0.134	-0.041	-0.001	0.099
leakage	0.032	-0.096	0.130	-0.106	0.575
SD	0.091	-0.001	0.196	0.053	-0.227
tot macr	0.034	-0.021	0.100	0.174	-0.039
DO (mgl-	-0.067	-0.051	-0.153	-0.254	0.150
temp	0.016	0.148	-0.253	-0.241	-0.346
condv	0.050	0.066	-0.180	-0.342	-0.011
pH	0.003	0.118	-0.252	-0.134	0.178

APPENDIX J: *C. gariepinus* SEED AND BAIT SUPPLY AND DEMAND

SENSITIVITY ANALYSIS ON POTENTIAL SUPPLY AND DEMAND FOR C. gari pinus SEED AND BAIT

ESTIMATED ANNUAL *C. gariepinus* HATCHERY PRODUCTION

Estimated Monthly Production

Month	**No. Fingerlings**
January	100,000
February	100,000
March	100,000
April	100,000
May	100,000
June	10,000
July	10,000
August	10,000
September	100,000
October	100,000
November	100,000
December	100,000
TOTAL	**930,000**

POTENTIAL ANNUAL DEMAND FOR C. gariepinus AS SEED

District	Number of Ponds	Pond Area (m2)	ON:CL = 3:1 SD = 1 fish/m2	ON:CL = 3:1 SD = 2 fish/m2	ON:CL = 3:1 SD = 3 fish/m2	CL only; SD = 1 fish/m2	CL only; SD = 2 fish/m2	CL only; SD = 2 fish/m2	ON:CL = 5:1 SD = 1 fish/m2	ON:CL = 5:1 SD = 2 fish/m2	ON:CL = 5:1 SD = 3 fish/m2	Average Demand
Kalangala	-	-	-	-	-	-	-	-	-	-	-	-
Kampala	21	5,447	1,634	3,268	4,902	5,447	10,894	16,341	2,724	5,447	8,171	6,536
Masaka	83	18,260	5,478	10,956	16,434	18,260	36,520	54,780	9,130	18,260	27,390	21,912
Mpigi	88	19,360	5,808	11,616	17,424	19,360	38,720	58,080	9,680	19,360	29,040	23,232
Wakiso	108	65,167	19,550	39,100	58,650	65,167	130,334	195,501	32,584	65,167	97,751	78,200
Mukono	178	39,160	11,748	23,496	35,244	39,160	78,320	117,480	19,580	39,160	58,740	46,992
Rakai	8	1,760	528	1,056	1,584	1,760	3,520	5,280	880	1,760	2,640	2,112
Iganga	136	29,920	8,976	17,952	26,928	29,920	59,840	89,760	14,960	29,920	44,880	35,904
Jinja	96	21,120	6,336	12,672	19,008	21,120	42,240	63,360	10,560	21,120	31,680	25,344
Busia	35	10,325	3,098	6,195	9,293	10,325	20,650	30,975	5,163	10,325	15,488	12,390
Bugiri	26	10,130	3,039	6,078	9,117	10,130	20,260	30,390	5,065	10,130	15,195	12,156
Mbarara	212	80,400	24,120	48,240	72,360	80,400	160,800	241,200	40,200	80,400	120,600	96,480
Ntungamo	74	16,280	4,884	9,768	14,652	16,280	32,560	48,840	8,140	16,280	24,420	19,536
TOTAL	1,065	317,329	95,199	190,397	285,596	317,329	634,658	951,987	158,665	317,329	475,994	380,795

Assessed at one production cycle per year

POTENTIAL DEMAND FOR *C. gariepinus* AS BAIT

MODEL 1: 3 fishermen to a trader

Scenario A: 10 lines to a fisherman

periods when traders would prefer to be supplied	% traders	number of traders	demand of bait traders would like from supplier				TOTAL (100%)
			42%	44%	11%	4%	
			500	3,000	7,500	10,000	
January	8	679	142,494	854,962	2,137,405	2,849,874	**5,984,735**
February	9	763	160,305	961,832	2,404,581	3,206,108	**6,732,826**
March	9	763	160,305	961,832	2,404,581	3,206,108	**6,732,826**
April	10	848	178,117	1,068,703	2,671,757	3,562,342	**7,480,918**
May	9	763	160,305	961,832	2,404,581	3,206,108	**6,732,826**
June	10	848	178,117	1,068,703	2,671,757	3,562,342	**7,480,918**
July	9	763	160,305	961,832	2,404,581	3,206,108	**6,732,826**
August	9	763	160,305	961,832	2,404,581	3,206,108	**6,732,826**
September	9	763	160,305	961,832	2,404,581	3,206,108	**6,732,826**
October	8	679	142,494	854,962	2,137,405	2,849,874	**5,984,735**
November	7	594	124,682	748,092	1,870,230	2,493,639	**5,236,643**
December	6	509	106,870	641,222	1,603,054	2,137,405	**4,488,551**
TOTAL	**100**	**8,482**	**1,781,171**	**10,687,026**	**26,717,565**	**35,623,420**	**74,809,182**

Scenario B: 20 lines to a fisherman

periods when traders would prefer to be supplied	% traders	number of traders	demand of bait traders would like from supplier				TOTAL (100%)
			42%	**44%**	**11%**	**4%**	
			500	**3,000**	**7,500**	**10,000**	
January	8	342	71,821	430,928	1,077,321	1,436,428	**3,016,499**
February	9	382	80,153	480,916	1,202,290	1,603,054	**3,366,413**
March	9	382	80,153	480,916	1,202,290	1,603,054	**3,366,413**
April	10	424	89,059	534,351	1,335,878	1,781,171	**3,740,459**
May	9	382	80,153	480,916	1,202,290	1,603,054	**3,366,413**
June	10	424	89,059	534,351	1,335,878	1,781,171	**3,740,459**
July	9	382	80,153	480,916	1,202,290	1,603,054	**3,366,413**
August	9	382	80,153	480,916	1,202,290	1,603,054	**3,366,413**
September	9	382	80,153	480,916	1,202,290	1,603,054	**3,366,413**
October	8	339	71,247	427,481	1,068,703	1,424,937	**2,992,367**
November	7	297	62,341	374,046	935,115	1,246,820	**2,618,321**
December	6	254	53,435	320,611	801,527	1,068,703	**2,244,275**

TOTAL	**100**	**4,241**	**890,586**	**5,343,513**	**13,358,783**	**17,811,710**	**37,404,591**

Scenario C: 30 lines to a fisherman

periods when traders would prefer to be supplied	% traders	number of traders	demand of bait traders would like from supplier				TOTAL (100%)
			42%	44%	11%	4%	
			500	3,000	7,500	10,000	
January	8	228	47,881	287,286	718,214	957,619	**2,011,000**
February	9	254	53,435	320,611	801,527	1,068,703	**2,244,275**
March	9	254	53,435	320,611	801,527	1,068,703	**2,244,275**
April	10	283	59,372	356,234	890,586	1,187,447	**2,493,639**
May	9	254	53,435	320,611	801,527	1,068,703	**2,244,275**
June	10	283	59,372	356,234	890,586	1,187,447	**2,493,639**
July	9	254	53,435	320,611	801,527	1,068,703	**2,244,275**
August	9	254	53,435	320,611	801,527	1,068,703	**2,244,275**
September	9	254	53,435	320,611	801,527	1,068,703	**2,244,275**
October	8	85	17,812	106,870	267,176	356,234	**748,092**
November	7	198	41,561	249,364	623,410	831,213	**1,745,548**
December	6	170	35,623	213,741	534,351	712,468	**1,496,184**
TOTAL	**100**	**2,827**	**593,724**	**3,562,342**	**8,905,855**	**11,874,473**	**24,936,394**

Average annual demand, Model 1 = 45,716,722

MODEL 2: 8 fishermen to 1 trader

Scenario A: 10 lines to a fisherman

periods when traders would prefer to be supplied	% traders	number of traders	demand of bait traders would like from supplier				TOTAL (100%)
			42%	44%	11%	4%	
			500	3,000	7,500	10,000	
January	8	254	53,435	320,611	801,527	1,068,703	**2,244,275**
February	9	286	60,115	360,687	901,718	1,202,290	**2,524,810**
March	9	286	60,115	360,687	901,718	1,202,290	**2,524,810**
April	10	318	66,794	400,763	1,001,909	1,335,878	**2,805,344**
May	9	286	60,115	360,687	901,718	1,202,290	**2,524,810**
June	10	318	66,794	400,763	1,001,909	1,335,878	**2,805,344**
July	9	286	60,115	360,687	901,718	1,202,290	**2,524,810**
August	9	286	60,115	360,687	901,718	1,202,290	**2,524,810**
September	9	286	60,115	360,687	901,718	1,202,290	**2,524,810**
October	8	254	53,435	320,611	801,527	1,068,703	**2,244,275**
November	7	223	46,756	280,534	701,336	935,115	**1,963,741**
December	6	191	40,076	240,458	601,145	801,527	**1,683,207**

TOTAL	100	3,181	667,939	4,007,635	10,019,087	13,358,783	28,053,443

Scenario B: 20 lines to a fisherman

periods when traders would prefer to be supplied	% traders	number of traders	demand of bait traders would like from supplier				TOTAL (100%)
			42%	44%	11%	4%	
			500	3,000	7,500	10,000	
January	8	128	26,933	161,598	403,995	538,661	**1,131,187**
February	9	143	30,057	180,344	450,859	601,145	**1,262,405**
March	9	143	30,057	180,344	450,859	601,145	**1,262,405**
April	10	159	33,397	200,382	500,954	667,939	**1,402,672**
May	9	143	30,057	180,344	450,859	601,145	**1,262,405**
June	10	159	33,397	200,382	500,954	667,939	**1,402,672**
July	9	143	30,057	180,344	450,859	601,145	**1,262,405**
August	9	143	30,057	180,344	450,859	601,145	**1,262,405**
September	9	143	30,057	180,344	450,859	601,145	**1,262,405**
October	8	127	26,718	160,305	400,763	534,351	**1,122,138**
November	7	111	23,378	140,267	350,668	467,557	**981,871**
December	6	95	20,038	120,229	300,573	400,763	**841,603**
TOTAL	**100**	**1,590**	**333,970**	**2,003,817**	**5,009,543**	**6,679,391**	**14,026,722**

Scenario C: 30 lines to a fisherman

periods when traders would prefer to be supplied	% traders	number of traders	demand of bait traders would like from supplier				TOTAL (100%)
			42%	44%	11%	4%	
			500	3,000	7,500	10,000	
January	8	86	17,955	107,732	269,330	359,107	**754,125**
February	9	95	20,038	120,229	300,573	400,763	**841,603**
March	9	95	20,038	120,229	300,573	400,763	**841,603**
April	10	106	22,265	133,588	333,970	445,293	**935,115**
May	9	95	20,038	120,229	300,573	400,763	**841,603**
June	10	106	22,265	133,588	333,970	445,293	**935,115**
July	9	95	20,038	120,229	300,573	400,763	**841,603**
August	9	95	20,038	120,229	300,573	400,763	**841,603**
September	9	95	20,038	120,229	300,573	400,763	**841,603**
October	8	32	6,679	40,076	100,191	133,588	**280,534**
November	7	74	15,585	93,511	233,779	311,705	**654,580**
December	6	64	13,359	80,153	200,382	267,176	**561,069**
TOTAL	**100**	**1,060**	**222,646**	**1,335,878**	**3,339,696**	**4,452,928**	**9,351,148**

Average Annual Demand, Model 2 = 17,143,771

MODEL 3: 15 Fishermen to 1 trader

Scenario A: 10 lines to a fisherman

periods when traders would prefer to be supplied	% traders	number of traders	demand of bait traders would like from supplier				TOTAL (100%)
			42%	44%	11%	4%	
			500	3,000	7,500	10,000	
January	8	136	28,499	170,992	427,481	569,975	**1,196,947**
February	9	153	32,061	192,366	480,916	641,222	**1,346,565**
March	9	153	32,061	192,366	480,916	641,222	**1,346,565**
April	10	170	35,623	213,741	534,351	712,468	**1,496,184**
May	9	153	32,061	192,366	480,916	641,222	**1,346,565**
June	10	170	35,623	213,741	534,351	712,468	**1,496,184**
July	9	153	32,061	192,366	480,916	641,222	**1,346,565**
August	9	153	32,061	192,366	480,916	641,222	**1,346,565**
September	9	153	32,061	192,366	480,916	641,222	**1,346,565**
October	8	136	28,499	170,992	427,481	569,975	**1,196,947**
November	7	119	24,936	149,618	374,046	498,728	**1,047,329**
December	6	102	21,374	128,244	320,611	427,481	**897,710**
TOTAL	**100**	**1,696**	**356,234**	**2,137,405**	**5,343,513**	**7,124,684**	**14,961,836**

Scenario B*: 20 lines to a fisherman*

periods when traders would prefer to be supplied	% traders	number of traders	demand of bait traders would like from supplier				TOTAL (100%)
			42%	44%	11%	4%	
			500	3,000	7,500	10,000	
January	8	68	14,364	86,186	215,464	287,286	**603,300**
February	9	76	16,031	96,183	240,458	320,611	**673,283**
March	9	76	16,031	96,183	240,458	320,611	**673,283**
April	10	85	17,812	106,870	267,176	356,234	**748,092**
May	9	76	16,031	96,183	240,458	320,611	**673,283**
June	10	85	17,812	106,870	267,176	356,234	**748,092**
July	9	76	16,031	96,183	240,458	320,611	**673,283**
August	9	76	16,031	96,183	240,458	320,611	**673,283**
September	9	76	16,031	96,183	240,458	320,611	**673,283**
October	8	68	14,249	85,496	213,741	284,987	**598,473**
November	7	59	12,468	74,809	187,023	249,364	**523,664**
December	6	51	10,687	64,122	160,305	213,741	**448,855**
TOTAL	**100**	**848**	**178,117**	**1,068,703**	**2,671,757**	**3,562,342**	**7,480,918**

***Scenario C*: 30 lines to a fisherman**

periods when traders would prefer to be supplied	% traders	number of traders	demand of bait traders would like from supplier				TOTAL (100%)
			42%	44%	11%	4%	
			500	3,000	7,500	10,000	
January	8	46	9,576	57,457	143,643	191,524	**402,200**
February	9	51	10,687	64,122	160,305	213,741	**448,855**
March	9	51	10,687	64,122	160,305	213,741	**448,855**
April	10	57	11,874	71,247	178,117	237,489	**498,728**
May	9	51	10,687	64,122	160,305	213,741	**448,855**
June	10	57	11,874	71,247	178,117	237,489	**498,728**
July	9	51	10,687	64,122	160,305	213,741	**448,855**
August	9	51	10,687	64,122	160,305	213,741	**448,855**
September	9	51	10,687	64,122	160,305	213,741	**448,855**
October	8	17	3,562	21,374	53,435	71,247	**149,618**
November	7	40	8,312	49,873	124,682	166,243	**349,110**
December	6	34	7,125	42,748	106,870	142,494	**299,237**
TOTAL	**100**	**565**	**118,745**	**712,468**	**1,781,171**	**2,374,895**	**4,987,279**

Average Annual Demand, Model 3 = 9,143,344

Average Supply and Demand

	supply	seed	bait	Balance
sum	930,000	320,546	25,144,192	
				(24,534,738)
	930,000	320,546	4,987,279	(4,377,825)

Fishermen's Bait Demand to Catch Nile Perch	% response (n = 76)
up to 500	24
500 - 1000	34
1000 - 1500	8
1500 - 2000	14
2000 - 3000	3
3000 - 4000	3
above 4000	14

Period of Peak Demand for Bait by Fishermen to Catch Nile Perch (month)	% response (n = 235)
January	1
February	1
March	4
April	22
May	14
June	14
July	15
August	20
September	5
October	2
November	1
December	1

APPENDIX K: CRITERIA USED BY FARMERS TO RANK WEALTH

Various criteria were used by participants **(*N* = 73)** to assess wealth status.

Additional job, nature of job, income levels and education

Local non-farm sources of income and their relationship to wealth ratings as viewed by participants.

Wealth Category	BMC	WBC	IBC
Wealthiest	Self-employed, business (commercial houses), civil servants, teachers, councillors, carpenters, clergy	Self-employed, traders, government jobs, business	Self employed, businesses (shops, housing, bakeries, etc), professionals (doctors)
Middle	Small business, casual labourers, wives work *chapati* makers, sell buns, dealers in local chickens, brick layers, working class, brick layers, fishermen, brewer, teachers, motorbike-taxi drivers, buy and sell maize, make crates, fish mongers	No jobs, teachers, small business	Self employed, small-business (brewing, hair dressers), charcoal burners, casual labourers, firewood cutter/sellers, employees
Poorest	Unemployed, fish mongers, casual workers, brewers	Seasonal workers, no permanent jobs, casual workers, no reliable income	Witch doctors, brick makers, casual labourers

Relationship between wealth ratings and species, breed and numbers of livestock

Wealth Category	BMC	WBC	IBC
Wealthiest	Some cattle (mostly local), goats, chickens	Cattle – cross breeds or exotics	Intensive poultry, piggeries, either several zero-grazers or several local cows
Middle	Some cattle, chickens and goats	Small animals mostly goats, local chickens, rabbits, pigs. About 2 local cows	A zero grazer or two, tethered pigs, about two local cattle, tethered or free range.
Poorest	Chickens and turkeys	Small animals, some rabbits, a few but usually no cattle (local)	Tethered cattle, one or two, local birds

Relationship between crop production practices and wea th ranking.

Wealth Category	BMC	WBC	IBC
Wealthiest	Coffee (Bugiri district), cassava (Busia district), sugarcane plantations, early adopters, surplus to sell	Coffee and banana plantations, eucalyptus trees, commercial tomato or other vegetable gardens	Mainly livestock and jobs
Middle	Small coffee gardens, supplemented with small business	Semi-subsistence farmers, small banana and coffee gardens, maize, sorghum and beans	Some gardens mostly for home consumption, sweet potatoes important followed by cassava among middle and poor. Depend on farming solely for survival
Poorest	Subsistence farmers	Subsistence farmers	Tenants

APPENDIX L: SENSITIVITY ANALYSIS – EXPERIMENTS

Experiment 1, Numbers

Parameter	Unit Change	Treatment I	II	III	IV
% marketable yield	20%				
Profit		-15%	-33%	-57%	-88%
profit (excluding labour costs)		-16%	-35%	-61%	-96%
returns to investment, farmer's view		-15%	-33%	-57%	-88%
returns on total investment, economist's view		-15%	-33%	-57%	-88%
returns to labour		-16%	-35%	-61%	-96%
returns to land		-15%	-33%	-57%	-88%
cost of per fish produced/break-even price		-33%	-33%	-33%	-33%
break-even production		0%	0%	0%	0%
profit operations cost ratio		-15%	-33%	-57%	-88%
cost capital	10%				
profit		-0.1%	0.4%	0.0%	0.0%
profit (excluding labour costs)		-0.1%	0.2%	0.0%	0.0%
returns to investment, farmer's view		-0.1%	0.4%	0.0%	0.0%
returns on total investment, economist's view		0.0%	0.4%	0.1%	0.0%
returns to labour		-0.1%	0.2%	0.0%	0.0%
returns to land		-0.1%	0.4%	0.0%	0.0%
cost of per fish produced/break-even price		-0.1%	0.0%	0.0%	0.0%
break-even production		-0.1%	0.0%	0.0%	0.0%
profit operations cost ratio		0.0%	0.5%	0.1%	0.0%
% marketable size	10%				
profit		-12%	-27%	-46%	-70%
profit (excluding labour costs)		-12%	-28%	-49%	-77%
returns to investment, farmer's view		-12%	-27%	-46%	-70%
returns on total investment, economist's view		-12%	-27%	-46%	-70%
returns to labour		-12%	-28%	-49%	-77%
returns to land		-12%	-27%	-45%	-70%
cost of per fish produced/break-even price		0%	0%	0%	0%
break-even production		0%	0%	0%	0%
profit operations cost ratio		-12%	-27%	-46%	-70%
fish prices	UShs. 100/-	36%	114%	396%	-1768%
profit		39%	128%	526%	-967%
profit (excluding labour costs)		36%	114%	396%	-1768%
returns to investment, farmer's view		36%	114%	396%	-1768%
returns on total investment, economist's view		39%	128%	526%	-967%
returns to labour		36%	114%	393%	-1810%
returns to land		0%	0%	0%	0%
cost of per fish produced/break-even price		33%	33%	33%	33%
break-even production		36%	114%	396%	-1768%
profit operations cost ratio					

feed prices	UShs. 25/-				
profit		-2%	11%	2%	2%
profit (excluding labour costs)		-2%	7%	2%	2%
returns to investment, farmer's view		-2%	11%	2%	2%
returns on total investment, economist's view		-1%	11%	3%	3%
returns to labour		-2%	7%	2%	2%
returns to land		-1%	11%	2%	2%
cost of per fish produced/break-even price		-2%	-2%	-2%	-2%
break-even production		-2%	-2%	-2%	-2%
profit operations cost ratio		0%	12%	4%	3%
seed prices	UShs. 25/-				
profit		-27%	42%	23%	19%
profit (excluding labour costs)		-33%	37%	22%	18%
returns to investment, farmer's view		36%	71%	61%	59%
returns on total investment, economist's view		-18%	49%	35%	34%
returns to labour		-33%	37%	22%	18%
returns to land		-27%	42%	23%	19%
cost of per fish produced/break-even price		-31%	-45%	-53%	-58%
break-even production		-31%	-45%	-53%	-58%
profit operations cost ratio		3%	60%	50%	49%

Experiment 1, Weight

Parameter	Unit Change	Treatment I	II	III	IV
% marketable yield	20%				
profit		-5%	-5%	-6%	-6%
profit (excluding labour costs)		-5%	-5%	-6%	-6%
returns to investment, farmer's view		-5%	-5%	-6%	-6%
returns to investment, economist's view		-5%	-5%	-6%	-6%
returns to labour		-5%	-5%	-6%	-6%
returns to land		-5%	-5%	-6%	-6%
cost of per fish produced/break-even price		0%	0%	0%	0%
break-even production		0%	0%	0%	0%
profit operations cost ratio		-5%	-5%	-6%	-6%
receipts per fish/receipts/kg		0%	0%	0%	0%
cost capital	10%				
profit		0.0%	0.0%	0.0%	0.0%
profit (excluding labour costs)		0.0%	0.0%	0.0%	0.0%
returns to investment, farmer's view		0.0%	0.0%	0.0%	0.0%
returns to investment, economist's view		0.0%	0.0%	0.0%	0.0%
returns to labour		0.0%	0.0%	0.0%	0.0%
returns to land		0.0%	0.0%	0.0%	0.0%
cost of per fish produced/break-even price		-0.1%	0.0%	0.0%	0.0%
break-even production		-0.1%	0.0%	0.0%	0.0%
profit operations cost ratio		0.0%	0.0%	0.0%	0.0%
receipts per fish/receipts/kg		0%	0%	0%	0%
% marketable size	10%				
profit		0.0%	0.0%	0.0%	0.0%
profit (excluding labour costs)		0.0%	0.0%	0.0%	0.0%
returns to investment, farmer's view		0.0%	0.0%	0.0%	0.0%
returns to investment, economist's view		0.0%	0.0%	0.0%	0.0%
returns to labour		0.0%	0.0%	0.0%	0.0%
returns to land		0.0%	0.0%	0.0%	0.0%
cost of per fish produced/break-even price		0.0%	0.0%	0.0%	0.0%
break-even production		0.0%	0.0%	0.0%	0.0%
profit operations cost ratio		0.0%	0.0%	0.0%	0.0%
receipts per fish/receipts/kg		20%	20%	20%	20%
fish prices per kg	UShs. 250/-				
profit		4%	5%	7%	7%
profit (excluding labour costs)		5%	5%	7%	7%
returns to investment, farmer's view		4%	5%	7%	7%
returns to investment, economist's view		4%	5%	7%	7%
returns to labour		5%	5%	7%	7%
returns to land		4%	5%	7%	7%
cost of per fish produced/break-even price		0%	0%	0%	0%
break-even production		17%	17%	17%	17%
profit operations cost ratio		4%	5%	7%	7%
receipts per fish/receipts/kg		-25%	-25%	-25%	-25%

feed prices per kg	UShs. 250/-				
profit		-1%	-1%	-1%	-1%
profit (excluding labour costs)		-1%	-1%	-1%	-1%
returns to investment, farmer's view		-1%	-1%	-1%	-1%
returns to investment, economist's view		0%	0%	0%	0%
returns to labour		-1%	-1%	-1%	-1%
returns to land		-1%	-1%	-1%	-1%
cost of per fish produced/break-even price		-2%	-2%	-2%	-2%
break-even production		-2%	-2%	-2%	-2%
profit operations cost ratio		1%	1%	0%	0%
receipts per fish/receipts/kg		0%	0%	0%	0%
seed prices	UShs. 25/-				
profit		-10%	-18%	-30%	-38%
profit (excluding labour costs)		-10%	-19%	-31%	-41%
returns to investment, farmer's view		45%	41%	35%	31%
returns to investment, economist's view		-2%	-4%	-9%	-12%
returns to labour		-10%	-19%	-31%	-41%
returns to land		-10%	-18%	-29%	-38%
cost of per fish produced/break-even price		-31%	-45%	-53%	-58%
break-even production		-31%	-45%	-53%	-58%
profit operations cost ratio		16%	19%	16%	12%
receipts per fish/receipts/kg		0%	0%	0%	0%

Experiment 2, numbers

Parameter	Unit Change	Treatment					
		I	II	III	IV	V	VI
% marketable yield	20%						
profit		70%	56%	77%	67%	54%	48%
profit (excluding labour costs)		61%	51%	67%	60%	50%	45%
returns to investment, farmer's view		70%	56%	77%	67%	54%	48%
returns on total investment, economist's view			70%	56%	77%	67%	54%
returns to labour		61%	51%	67%	60%	50%	45%
returns to land		289%	114%	287%	158%	92%	65%
cost of per fish produced/break-even price		-33%	-33%	-33%	-33%	-33%	-33%
break-even production		0%	0%	0%	0%	0%	0%
profit operations cost ratio		70%	56%	77%	67%	54%	48%
cost capital	10%						
profit		0%	0%	0%	0%	0%	0%
profit (excluding labour costs)		0%	0%	0%	0%	0%	0%
returns to investment, farmer's view		0%	0%	0%	0%	0%	0%
returns on total investment, economist's view		0%	0%	0%	0%	0%	0%
returns to labour		0%	0%	0%	0%	0%	0%
returns to land		0%	-1%	0%	0%	1%	0%
cost of per fish produced/break-even price		0%	0%	0%	0%	0%	0%
break-even production		0%	0%	0%	0%	0%	0%
profit operations cost ratio		0%	0%	0%	0%	0%	0%
% marketable size	10%						
profit		14%	14%	15%	15%	15%	17%
profit (excluding labour costs)		14%	14%	15%	15%	14%	17%
returns to investment, farmer's view		14%	14%	15%	15%	15%	17%
returns on total investment, economist's view		14	15%	15	15	15	17
returns to labour		14%	14%	15%	15%	14%	17%
returns to land		17%	17%	19%	19%	18%	22%
cost of per fish produced/break-even price		0%	0%	0%	0%	0%	0%
break-even production		0%	0%	0%	0%	0%	0%
profit operations cost ratio		14%	14%	15%	15%	15%	17%
fish prices	UShs. 100/-						
profit		-80%	-53%	-91%	-71%	-46%	-38%
profit (excluding labour costs)		-61%	-45%	-68%	-57%	-40%	-35%
returns to investment, farmer's view		-80%	-53%	-91%	-71%	-46%	-38%
returns on total investment, economist's view		80	53	91	71	46	38
returns to labour		-61%	-45%	-68%	-57%	-40%	-35%
returns to land		154%	-478%	125%	362%	-169%	-69%
break-even price		0%	0%	0%	0%	0%	0%
break-even production		0%	0%	0%	0%	0%	0%
profit operations cost ratio		-80%	-53%	-91%	-71%	-46%	-38%

feed prices	UShs. 25/-						
profit		0%	-5%	-117%	-50%	-18%	-15%
profit (excluding labour costs)		0%	-4%	-43%	-33%	-15%	-14%
returns to investment, farmer's view		0%	-5%	-117%	-50%	-18%	-15%
returns on total investment, economist's view		0	6	125	57	23	22
returns to labour		0%	-4%	-43%	-33%	-15%	-14%
returns to land		0%	10%	15%	30%	190%	-35%
break-even price		0%	1%	4%	6%	6%	7%
break-even production		0%	1%	4%	6%	6%	7%
profit operations cost ratio		0%	-6%	-128%	-60%	-25%	-25%
seed prices	UShs. 25/-; 67/-						
profit		17%	14%	17%	15%	12%	9%
profit (excluding labour costs)		16%	13%	16%	14%	11%	8%
returns to investment, farmer's view		48%	45%	47%	46%	44%	42%
returns on total investment, economist's view		31	27	28	26	24	19
returns to labour		16%	13%	16%	14%	11%	8%
returns to land		29%	20%	28%	23%	17%	11%
break-even price		-35%	-33%	-25%	-24%	-27%	-18%
break-even production		14%	15%	20%	20%	19%	24%
profit operations cost ratio		39%	35%	34%	31%	31%	23%

Experiment 2, weight

Parameter	Unit Change	Treatment					
		I	II	III	IV	V	VI
% marketable yield	20%						
profit		79%	64%	101%	88%	47%	59%
profit (excluding labour costs)		67%	57%	84%	75%	44%	55%
returns to investment, farmer's view		79%	64%	101%	88%	47%	59%
returns on total investment, economist's view		67	79%	64%	101%	88%	47%
returns to labour		67%	57%	84%	75%	44%	55%
returns to land		914%	173%	-1305%	679%	69%	98%
cost of per fish produced/break-even price		-33%	-33%	-33%	-33%	-33%	-33%
break-even production		0%	0%	0%	0%	0%	0%
profit operations cost ratio		79%	64%	101%	88%	47%	59%
cost capital	10%						
profit		0%	0%	-5%	0%	0%	0%
profit (excluding labour costs)		0%	0%	0%	0%	0%	0%
returns to investment, farmer's view		0%	0%	-5%	0%	0%	0%
returns on total investment, economist's view		0%	0%	-5%	1%	0%	0%
returns to labour		0%	0%	0%	0%	0%	0%
returns to land		0%	0%	0%	0%	0%	4%
cost of per fish produced/break-even price		0%	0%	0%	0%	0%	0%
break-even production		0%	0%	0%	0%	0%	0%
profit operations cost ratio		0%	0%	-5%	1%	0%	0%
% marketable size	10%						
profit		0%	0%	0%	0%	0%	0%
profit (excluding labour costs)		0%	0%	0%	0%	0%	0%
returns to investment, farmer's view		0%	0%	0%	0%	0%	0%
returns on total investment, economist's view			0%	0%	0%	0%	0%
returns to labour		0%	0%	0%	0%	0%	0%
returns to land		0%	0%	0%	0%	0%	0%
cost of per fish produced/break-even price		-11%	-11%	-11%	-11%	-11%	-11%
break-even production		0%	0%	0%	0%	0%	0%
profit operations cost ratio		0%	0%	0%	0%	0%	0%
fish prices	UShs. 100/-						
profit		-78%	-52%	-155%	-105%	-30%	-48%
profit (excluding labour costs)		-56%	-42%	-86%	-70%	-27%	-42%
returns to investment, farmer's view		-78%	-52%	-155%	-105%	-30%	-48%
returns on total investment, economist's view		78	52	155	105	30	48
returns to labour		-56%	-42%	-86%	-70%	-27%	-42%
returns to land		75%	269%	52%	69%	-63%	-214%
cost of per fish produced/break-even price		0%	0%	0%	0%	0%	0%
break-even production		0%	0%	0%	0%	0%	0%
profit operations cost ratio		-78%	-52%	-155%	-105%	-30%	-48%
feed prices	UShs. 25/-						
profit		0%	-9%	64%	279%	-11%	-33%
profit (excluding labour costs)		0%	-6%	980%	-141%	-10%	-27%
returns to investment, farmer's view		0%	-9%	64%	279%	-11%	-33%
returns on total investment, economist's view		0	10	62	288	16	41
returns to labour		0%	-6%	980%	-141%	-10%	-27%
returns to land		0%	5%	11%	18%	-36%	158%
cost of per fish produced/break-even price		0%	1%	4%	6%	6%	7%
break-even production		0%	1%	4%	6%	6%	7%
profit operations cost ratio		0%	-10%	62%	291%	-18%	-44%
seed prices	UShs. 25/-; 67/-						

profit	19%	16%	20%	19%	10%	12%
profit (excluding labour costs)	17%	15%	19%	17%	10%	11%
returns to investment, farmer's view	49%	47%	50%	48%	43%	44%
returns on total investment, economist's view	32	29	31	29	23	22
returns to labour	17%	15%	19%	17%	10%	11%
returns to land	34%	25%	39%	33%	13%	16%
cost of per fish produced/break-even price	-35%	-33%	-25%	-24%	-27%	-18%
break-even production	14%	15%	20%	20%	19%	24%
profit operations cost ratio	40%	36%	37%	34%	29%	25%

C. gariepinus bait, numbers

Parameter	Unit Change	Treatment				
		80	70	60	50	40
manure	UShs. 25/-					
profit		0%	0%	-2%	1%	0%
profit (excluding labour costs)		0%	0%	-1%	1%	0%
returns to investment, farmer's view		0%	0%	-2%	1%	0%
returns on total investment, economist's view		0%	-1%	-2%	1%	0%
returns to labour		0%	0%	-1%	1%	0%
returns to land		0%	0%	-2%	1%	0%
cost of per fish produced/break-even price		0%	0%	0%	0%	0%
break-even production		0%	0%	0%	0%	0%
ratio of net profit to operating costs		0%	-1%	-2%	1%	0%
% marketable size	10%					
profit		29%	50%	189%	-108%	-42%
profit (excluding labour costs)		27%	44%	126%	-153%	-47%
returns to investment, farmer's view		61%	88%	261%	-110%	-28%
returns on total investment, economist's view		47	71	229	110	34
returns to labour		27%	44%	126%	-153%	-47%
returns to land		29%	50%	189%	-108%	-42%
cost of per fish produced/break-even price		-19%	-19%	-19%	-19%	-19%
break-even production		-19%	-19%	-19%	-19%	-19%
profit operations cost ratio		59%	85%	256%	-110%	-29%
bait prices	UShs. 5/-					
profit		-96%	-49%	-29%	-19%	-12%
profit (excluding labour costs)		-123%	-56%	-32%	-20%	-13%
returns to investment, farmer's view		-96%	-49%	-29%	-19%	-12%
returns on total investment, economist's view		96	49%	29%	19%	12%
returns to labour		-123%	-56%	-32%	-20%	-13%
returns to land		-96%	-49%	-29%	-19%	-12%
break-even price		0%	0%	0%	0%	0%
break-even production		-14%	-14%	-14%	-14%	-14%
profit operations cost ratio		-96%	-49%	-29%	-19%	-12%
feed prices	UShs. 50/-					
profit		-31%	-23%	-17%	-12%	-9%
profit (excluding labour costs)		-34%	-24%	-18%	-13%	-9%
returns to investment, farmer's view		-31%	-23%	-17%	-12%	-9%
returns on total investment, economist's view		31	23%	17%	-12%	-9%
returns to labour		-34%	-24%	-18%	-13%	-9%
returns to land		-31%	-23%	-17%	-12%	-9%
break-even price		0%	0%	0%	0%	0%
break-even production		-17%	-17%	-17%	-17%	-17%
profit operations cost ratio		-31%	-23%	-17%	-12%	-9%
seed prices	UShs. 5/-					
profit		-23%	-30%	-42%	-73%	-273%
profit (excluding labour costs)		-22%	-28%	-39%	-65%	-182%
returns to investment, farmer's view		-42%	-47%	-57%	-80%	-230%
returns on total investment, economist's view			-40%	-45%	-55%	-79%
returns to labour		-22%	-28%	-39%	-65%	-182%
returns to land		-23%	-30%	-42%	-73%	-274%
cost of per fish produced/break-even price		30%	30%	30%	30%	30%
break-even production		30%	30%	30%	30%	30%
profit operations cost ratio		-41%	-46%	-56%	-79%	-233%

C. gariepinus bait, weight

Parameter	Unit Change	Treatment				
		80	70	60	50	40
manure	UShs. 25/-					
profit		0%	0%	-2%	1%	0%
profit (excluding labour costs)		0%	0%	-1%	1%	0%
returns to investment, farmer's view		0%	0%	-2%	1%	0%
returns on total investment, economist's view		0%	-1%	-2%	1%	0%
returns to labour		0%	0%	-1%	1%	0%
returns to land		0%	0%	-2%	1%	0%
cost of per fish produced/break-even price		0%	0%	0%	0%	0%
break-even production		0%	0%	0%	0%	0%
profit operations cost ratio		0%	-1%	-2%	1%	0%
% marketable size	10%					
profit		-31%	-47%	-182%	64%	20%
profit (excluding labour costs)		-29%	-41%	-111%	88%	22%
returns to investment, farmer's view		-31%	-47%	-182%	64%	20%
returns on total investment, economist's view			-31%	-47%	-182%	64%
returns to labour		-29%	-41%	-111%	88%	22%
returns to land		-31%	-47%	-182%	64%	20%
cost of per fish produced/break-even price		25%	43%	67%	100%	150%
break-even production		22900%	22900%	22900%	22900%	22900%
profit operations cost ratio		-31%	-47%	-182%	64%	20%
fish prices per kg	UShs. 1,000/-					
profit		-31%	-23%	-17%	-12%	-9%
profit (excluding labour costs)		-34%	-24%	-18%	-13%	-9%
returns to investment, farmer's view		-31%	-23%	-17%	-12%	-9%
returns on total investment, economist's view			-31%	-23%	-17%	-12%
returns to labour		-34%	-24%	-18%	-13%	-9%
returns to land		-31%	-23%	-17%	-12%	-9%
cost of per fish produced/break-even price		0%	0%	0%	0%	0%
break-even production		-17%	-17%	-17%	-17%	-17%
profit operations cost ratio		-31%	-23%	-17%	-12%	-9%
feed prices per kg	UShs. 50/-					
profit		-1.1%	-2.0%	-8.4%	4.0%	1.6%
profit (excluding labour costs)		-1.1%	-1.8%	-5.3%	5.5%	1.8%
returns to investment, farmer's view		-1.1%	-2.0%	-8.4%	4.0%	1.6%
returns on total investment, economist's view			-1.6%	-2.5%	-8.8%	3.5%
returns to labour		-1.1%	-1.8%	-5.3%	5.5%	1.8%
returns to land		-1.1%	-2.0%	-8.4%	3.9%	1.6%
cost of per fish produced/break-even price		0.5%	0.5%	0.5%	0.5%	0.5%
break-even production		0.5%	0.5%	0.5%	0.5%	0.5%
profit operations cost ratio		-1.6%	-2.5%	-8.8%	3.4%	1.1%
		0.0%	0.0%	0.0%	0.0%	0.0%
seed prices per fish	UShs. 5/-					
profit		-23%	-31%	-44%	-76%	-328%
profit (excluding labour costs)		-22%	-29%	-40%	-67%	-205%
returns to investment, farmer's view		-43%	-48%	-58%	-82%	-271%
returns on total investment, economist's view			-40%	-46%	-56%	-81%
returns to labour		-22%	-29%	-40%	-67%	-205%
returns to land		-23%	-31%	-44%	-76%	-329%
cost of per fish produced/break-even price		30%	30%	30%	30%	30%
break-even production		30%	30%	30%	30%	30%
profit operations cost ratio		-41%	-47%	-57%	-82%	-275%